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VOLUME V, NUMBER 12

DECEMBER 1964

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

In August 1959, the President directed the Secretary of Health, Education, and Welfare to intensify Departmental activities in the field of radiological health. The Department was assigned responsibility within the Executive Branch for the collation, analysis and interpretation of data on environmental radiation levels. The Department delegated this responsibility to the Division of Radiological Health, Public Health Service.

Radiological Health Data is published by the Public Health Service on a monthly basis. Data are provided to the Division of Radiological Health by other Federal agencies, State health departments, and foreign governments. Pertinent original data and interpretive papers are invited from investigators. Accepted material will be appropriately credited. The reports are reviewed by a Board of Editorial Advisors with representatives from the following Federal agencies:

Department of Health, Education, and Welfare
Atomic Energy Commission
Department of Defense
Department of Agriculture
Department of Commerce

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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service • Division of Radiological Health

Section I—Air and Fallout

FISSION PRODUCT BETA ACTIVITY IN AIRBORNE PARTICULATES AND PRECIPITATION

Continuous surveillance of gross beta activity in air and precipitation provides one of the earliest and most sensitive indications of changes in environmental fission product activity. Although this surveillance does not provide enough information to assess human radiation exposure from fallout, it is widely used as the basis of alerting systems for determining when to intensify monitoring in other phases of the environment.

Surveillance data from a number of national programs are published monthly and summarized periodically to show current and long-range trends of atmospheric radioactivity in the Western Hemisphere. Data provided by programs of the Public Health Service, the Canadian Department of National Health and Welfare, the Mexican Commission of Nuclear Energy, and the Pan American Health Organization are presented individually in tabular form and are also compared in beta concentration isograms.

1. Radiation Surveillance Network August 1964

Division of Radiological Health, Public Health Service

Surveillance of atmospheric radioactivity in the United States is conducted by the Radiation Surveillance Network (RSN) of the PHS Division of Radiological Health which regularly gathers samples from 73 stations distributed throughout the country (figure 1). Most of the stations are operated by State health department personnel.

The alerting function of the network is provided by field estimates of the gross beta activity of airborne particulates on the filters. These determinations are performed about 5 hours after the end of the sampling period to allow for decay of naturally-occurring radon daughters. The network station operators regularly submit their field estimates to the Radiation Surveillance Center, Division of Radiological Health, Washington, D. C. These field estimates are reported elsewhere on a monthly basis (*1*). When unusually high air levels are reported, appropriate Federal and State officials are promptly notified.

Air

Airborne particulates are collected continuously on a carbon-loaded cellulose dust filter 4 inches in diameter. A volume of about 1800 cubic meters of air is drawn through the filter during the 24-hour sampling period by a high volume centrifugal blower.

The filters are forwarded to the Radiation Surveillance Network laboratory in Rockville, Maryland, where the gross beta activity is measured using a thin-window, gas-flow proportional counter, calibrated with a Sr^{90}–Y^{90} standard. Each filter is counted at least 3 days after the end of the sampling period and again 7 days later. The initial 3-day aging of the sample eliminates interference from naturally-occurring radon and thoron daughters. By using the two counts and the Way-Wigner formula (*2*), the age of fission products is estimated, and the activity extrapolated to the

FIGURE 1.—RADIATION SURVEILLANCE NETWORK SAMPLING STATIONS

time of collection.[1] The daily concentrations and estimated ages of selected samples are reported by the PHS in a monthly RSN report (*1*). The August 1964 average gross beta concentrations in air for RSN stations are given in table 1. Time profiles of gross beta activity in air for eight RSN stations are shown in figure 2.

Precipitation

Continuous sampling for total precipitation is conducted at most stations on a daily basis, using funnels with collection areas of 0.4 square meter. A 500-ml aliquot of the collected precipitation is evaporated to dryness, and the residue is forwarded to the laboratory for analysis. If the collected sample is between 200 and 500 ml, the entire sample is evaporated. When a sample is smaller than 200 ml (equivalent to 0.5 mm or 0.02 inches of rainfall), the volume of precipitation is reported, but no analysis is made.

In the laboratory the gross beta activity in precipitation is determined by counting the evaporated sample by the same method used for analyzing the air filters, including the extrapolation to time of collection. Deposition for the sample is determined by:

$$D = \frac{CP}{1000}$$

where D is the deposition in nc/m^2, C is the concentration in pc/liter, and P is the depth of precipitation in mm. The individual values of deposition and depth of precipitation are totaled for the month, and the average concentration for the month, $\overline{C}$, is determined by:

$$\overline{C} = \frac{\Sigma D}{\Sigma P} \times 1000$$

The August 1964 average concentrations and total depositions are given in table 1.

[1] If a sample contains a mixture of fresh and old fission products, the age estimated by the Way-Wigner formula is some intermediate value and cannot be used for estimating date of formation.

TABLE 1.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, AUGUST 1964

Station location		Air surveillance				Precipitation measurements		
		Number of samples	Gross beta activity (pc/m³)			Last profile in *RHD*	Average concentration (pc/liter)	Total deposition (nc/m²)
			Maximum	Minimum	Average [a]			
Ala:	Montgomery	21	0.95	<0.10	0.36	Aug 64	200	23.4
Alaska:	Adak	13	0.43	<0.10	0.19	Nov 64		
	Anchorage	24	0.21	<0.10	0.12	Jul 64	270	11.7
	Attu Island	31	0.52	<0.10	0.20	Dec 64		
	Fairbanks	27	0.59	<0.10	0.23	Aug 64	220	15.6
	Juneau	10	0.30	<0.10	0.14	Sep 64	200	8.0
	Kodiak	23	0.54	<0.10	0.16	Oct 64		
	Nome	[b]						
	Point Barrow							
	St. Paul Island	28	0.42	<0.10	0.13	Mar 64		
Ariz:	Phoenix	31	0.91	<0.10	0.26	Sep 64		
Ark:	Little Rock	31	0.92	<0.10	0.44	Sep 64	200	21.4
Calif:	Berkeley	20	0.46	<0.10	0.21	Oct 64	[c]—	—
	Los Angeles	21	0.58	0.20	0.38	Feb 64	—	—
Canal Zone:	Ancon	16	0.27	<0.10	0.12	Nov 64		
Colo:	Denver	28	1.6	0.15	0.66	Oct 64	460	10.2
Conn:	Hartford	30	1.7	<0.10	0.71	Oct 64	250	11.9
Del:	Dover	20	1.8	0.24	0.86	Aug 64		
D. C:	Washington	30	2.7	0.16	0.83	Aug 64	270	10.6
Fla:	Jacksonville	27	1.4	<0.10	0.38	Sep 64	210	35.5
	Miami	28	1.4	<0.10	0.48	Oct 64	210	18.1
Ga:	Atlanta					Jul 64	210	18.1
Guam:	Agana	31	0.14	<0.10	0.10	Apr 64		
Hawaii:	Honolulu	31	0.66	<0.10	0.31	Dec 64	260	3.8
Idaho:	Boise	31	1.9	0.16	0.72	Dec 64	230	0.5
Ill:	Springfield	29	1.1	0.16	0.63	Mar 64	270	7.4
Ind:	Indianapolis	29	2.2	0.24	0.65	Jul 64	450	11.2
Iowa:	Iowa City	30	1.1	<0.10	0.55	Nov 64	240	18.3
Kans:	Topeka	14	0.87	0.24	0.45	Jul 64	210	18.6
Ky:	Frankfort	30	1.2	0.15	0.66	Feb 64	320	4.9
La:	New Orleans	28	0.52	<0.10	0.22	Mar 64	200	27.1
Maine:	Augusta	30	1.6	<0.10	0.76	Mar 64	250	34.5
	Presque Isle	27	1.5	<0.10	0.62	Nov 64		
Md:	Baltimore	21	1.5	<0.10	0.73	Oct 64	330	13.6
	Rockville	05	0.86	0.54	0.79	Mar 64		
Mass:	Lawrence	31	2.1	<0.10	0.81	Aug 64	390	13.5
	Winchester	30	2.2	<0.10	0.81	Dec 64	630	21.7
Mich:	Lansing	31	2.8	0.24	0.90	Feb 64	300	29.1
Minn:	Minneapolis	31	0.80	<0.10	0.34	Mar 64	220	29.2
Miss:	Jackson	31	1.2	<0.10	0.42	Apr 64	230	21.4
	Pascagoula					Dec 64		
Mo:	Jefferson City	31	0.75	0.15	0.42	Jul 64	<200	4.9
Mont:	Helena	28	1.4	0.13	0.72	Nov 64	310	9.0
Nebr:	Lincoln	12	0.73	<0.10	0.34			
Nev:	Las Vegas	28	1.4	0.13	0.52	Aug 64		
N. H:	Concord	21	2.2	<0.10	0.84	Feb 64		
N. J:	Trenton	31	1.5	0.21	0.72	Apr 64		
N. Mex:	Santa Fe	29	1.9	<0.10	0.43	Nov 64	230	8.8
N. Y:	Albany	21	2.1	<0.10	0.82	Jul 64	270	4.7
	Buffalo	21	2.1	<0.10	0.92	Nov 64		
	New York	27	1.8	0.22	0.87	Dec 64		
N. C:	Gastonia	30	1.5	<0.10	0.63	Nov 64	220	25.3
N. Dak:	Bismarck	29	1.5	0.18	0.62	Feb 64	290	6.8
Ohio:	Cincinnati	20	1.2	0.28	0.62	Aug 64		
	Columbus	31	2.0	0.16	0.80	Apr 64	450	17.8
	Painesville	31	2.2	0.16	0.96	Oct 64	290	22.3
Okla:	Oklahoma City	28	0.81	<0.10	0.24	Apr 64	200	6.0
	Ponca City	30	0.79	<0.10	0.28	Oct 64	204	52.4
Ore:	Portland	31	2.1	0.17	0.54	Oct 63	230	6.7
Pa:	Harrisburg	30	3.0	<0.10	0.85	Jul 64	200	2.5
P. R:	San Juan	06	0.82	<0.10	0.52	Mar 64	200	9.8
R. I:	Providence	29	3.6	<0.10	0.92	Jan 64	260	14.8
S. C:	Columbia	28	0.96	<0.10	0.45	Dec 64	250	56.9
S. Dak:	Pierre	30	1.1	0.14	0.47	Sep 64	<200	2.3
Tenn:	Nashville	31	1.2	<0.10	0.56	Jan 64	240	32.2
Tex:	Austin	31	0.45	<0.10	0.19	Aug 64	200	8.7
	El Paso	30	1.3	0.12	0.33	Jan 64	220	7.2
Utah:	Salt Lake City	31	0.98	0.25	0.49	Aug 64	970	5.2
Vt:	Barre	31	2.4	<0.10	0.91	Sep 64	300	28.8
Va:	Richmond	31	1.2	0.12	0.52	Sep 64	370	24.5
Wash:	Seattle	30	0.73	<0.10	0.18	Jul 64	230	6.4
W. Va:	Charleston	30	1.3	0.17	0.71	Dec 64	290	15.8
Wis:	Madison	30	1.4	0.15	0.71	Sep 64	240	18.1
Wyo:	Cheyenne	31	1.2	0.21	0.58	Aug 64	<200	8.5
Network summary		1,857	3.5	<0.10	0.53		279	16.4

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed before the average.
[b] Blank indicates no report received.
[c] Dash indicates no precipitation sample collected.

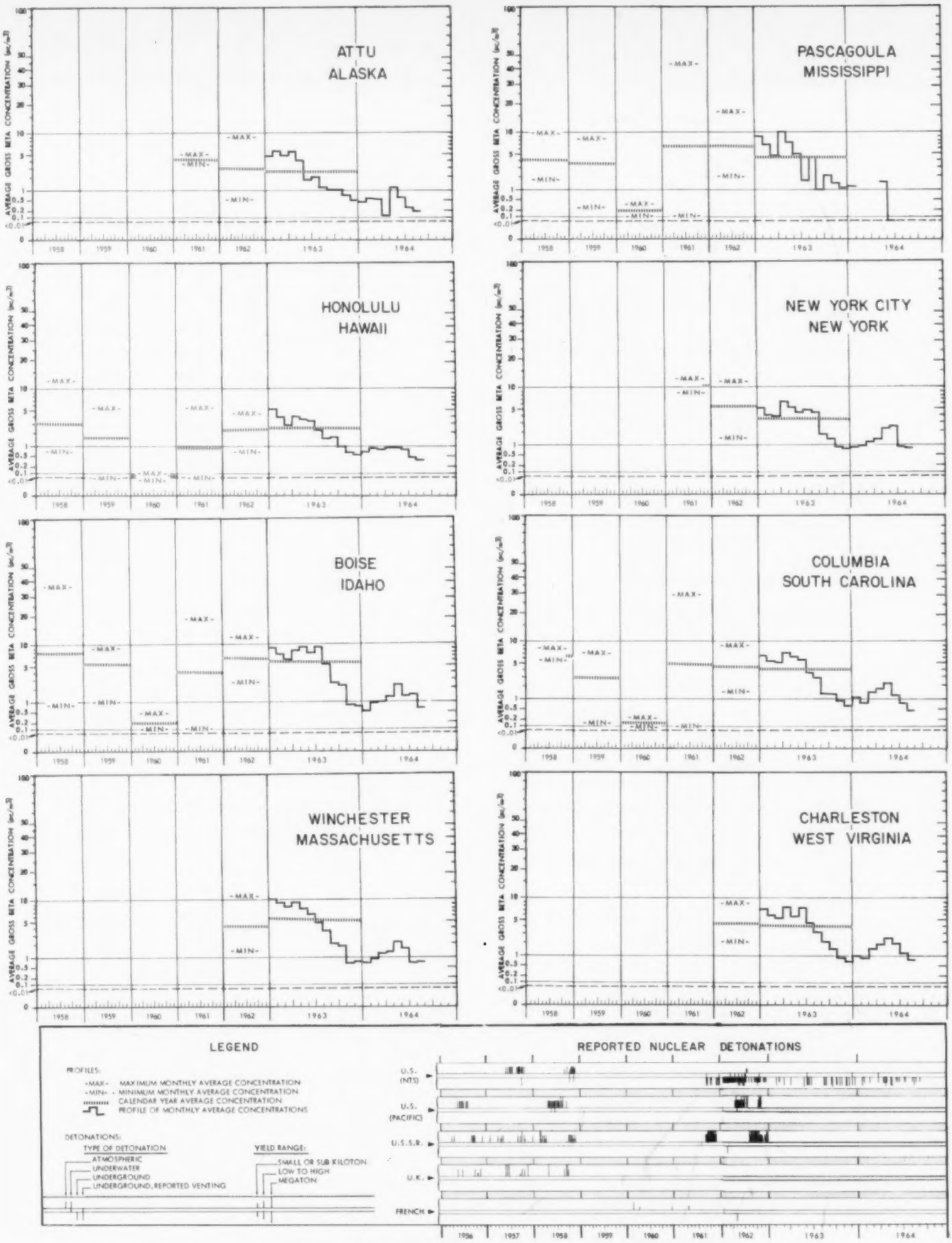

FIGURE 2.—MONTHLY AND YEARLY PROFILES OF BETA ACTIVITY IN AIR—RADIATION SURVEILLANCE NETWORK, 1958—AUGUST 1964

2. Canadian Air Monitoring Program [2] August 1964

Department of National Heatlh and Welfare

The Radiation Protection Division of the Canadian Department of National Health and Welfare monitors air and precipitation in connection with its Radioactive Fallout Study Program. Twenty-four collection stations are located at airports (figure 2), where the sampling equipment is operated by personnel from the Meteorological Services Branch of the Department of Transport. Detailed discussions of the sampling procedures, methods of analysis, and interpretation of results of the radioactive fallout program are contained in reports of the Department of National Health and Welfare (*3–7*).

[2] Data from *Radiation Protection Programs Vol 2, No. 9:* 11–24, Radiation Protection Division, Canadian Department of National Health and Welfare, Ottawa, Canada (Sept. 1964).

Air

Each air sample involves the collection of particulates from about 650 cubic meters of air drawn through a high-efficiency 4-inch-diameter filter during a 24-hour period. These filters are sent daily to the Radiation Protection Division Laboratory in Ottawa. At the laboratory, a 2-inch-diameter disk is cut from each filter and counted with a thin-end-window, gas-flow, Geiger-Mueller counter system, calibrated with a Sr^{90}–Y^{90} standard. Four successive measurements are made on each filter to permit correction for natural activities and for the decay of short-lived fission products. The results are extrapolated to the end of the sampling period. Canadian air data for August 1964 are given in table 2 and presented in conjunction with U. S. and Mexican data by an isogram map (figure 5).

TABLE 2.—GROSS BETA ACTIVITY IN SURFACE AIR AND PRECIPITATION, CANADA

Station	Air surveillance				Precipitation data	
	Number of samples	Gross beta activity (pc/m³)			Average concentration (pc/liter)	Total deposition (nc/m²)
		Maximum	Minimum	Average		
Calgary	30	1.4	0.1	0.7	2,389	12.7
Coral Harbour	31	0.8	0.1	0.3	282	12.8
Edmonton	31	1.0	0.1	0.5	367	26.0
Ft. Churchill	29	0.9	0.1	0.4	436	13.3
Ft. William	30	1.0	0.1	0.4	255	26.7
Fredericton	30	1.3	0.1	0.5	169	19.3
Goose Bay	31	1.3	0.1	0.5	217	22.6
Halifax	30	1.1	0.1	0.5	303	24.0
Inuvik	31	1.0	0.1	0.4	355	6.8
Montreal	31	2.2	0.1	0.7	208	19.5
Moosonee	31	1.2	0.1	0.4	178	30.8
Ottawa	31	2.6	0.1	0.6	380	13.2
Quebec	31	1.9	0.1	0.7	222	32.0
Regina	31	1.2	0.1	0.7	370	19.0
Resolute	29	0.8	0.0	0.2	3,350	79.9
St. John's, Nfld	30	1.0	0.1	0.4	175	27.3
Saskatoon	31	1.3	0.2	0.7	425	24.9
Sault Ste. Marie	29	1.8	0.1	0.6	249	20.7
Toronto	30	1.8	0.1	0.7	181	26.1
Vancouver	31	0.9	0.1	0.3	520	19.6
Whitehorse	31	1.0	0.1	0.3	279	14.3
Windsor	31	1.6	0.1	0.6	166	24.8
Winnipeg	29	0.9	0.2	0.5	286	25.1
Yellowknife	30	1.1	0.2	0.6	1,207	12.0
Network summary		2.6	0.0	0.5	540	23.1

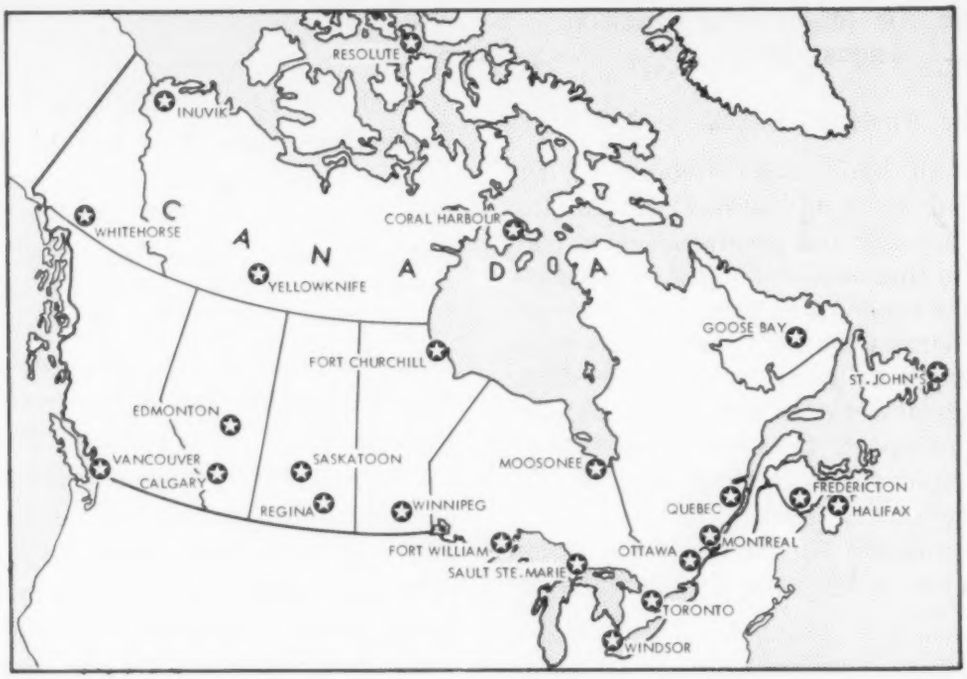

FIGURE 3.—CANADIAN AIR AND PRECIPITATION SAMPLING STATIONS

Precipitation

The amount of radioactive fallout deposited on the ground is determined from measurements on material collected in special polyethylene-lined rainfall pots. The collection period for each sample is one month. After transfer of the water to the sample container, the polyethylene liner is removed, packed with the sample, and sent to the laboratory.

Strontium and cesium carriers are added to all samples on arrival at the laboratory. Other carriers are also added to selected samples according to the specific radionuclides to be determined. The samples are then filtered and the filtrate evaporated to near dryness. The filter paper containing insoluble matter is ignited together with the polyethylene liner at 450° C. The ash is combined with the soluble fraction, transferred to a glass planchet, evaporated under an infra-red lamp and then counted with a thin-end-window Geiger-Mueller counter calibrated with a Sr^{90}–Y^{90} source. Gross beta activities for August 1964 samples are given in table 2. Radionuclide analyses are reported quarterly in *RHD*.

3. Mexican Air Monitoring Program August 1964

National Commission of Nuclear Energy

The Radiation Surveillance Network of Mexico was established by the *Comisión Nacional de Energía Nuclear* (CNEN), Mexico City. From 1952 to 1961 the network was directed by the Institute of Physics of the University of Mexico, under contract to the CNEN (*8–12*).

In 1961 the CNEN appointed its Division of Radiological Protection (DRP) to establish a new Radiation Surveillance network. This network consists of 17 stations (see figure 3), twelve of which are located at airports and operated by airline personnel. The remaining five stations are located at Mexico City, Mérida, Veracruz, San Luis Potosí and Ensenada. Staff members of the DRP operate the station at Mexico City while the other four stations are manned by members of the Centro de Previsión del Golfo de México, the Chemistry Department of the University of Merída, the Institute de

Zonas desérticas of the University of San Luis Potosí, and the Escuela Superior de Ciencias Marinas of the University of Baja California, respectively.

Sampling

The sampling procedure involves drawing air for 24 hours a day, 3 or 4 days a week at the rate of approximately 1,200 cubic meters per day, through a high-efficiency, 6 x 8-inch glass fiber filter, using high volume samplers. After each 24-hour sampling period, the filter is removed and forwarded via air mail to the "Laboratorio de Estudios sobre Contaminación Radiactiva", CNEN, in Mexico City for assay of gross beta activity. A minimum of 3 or 4 days after collection is allowed for decay of radon and thoron daughter natural radioactivity. Data are not extrapolated to time of collection.

Results

The maximum, minimum and average fission product beta concentrations in surface air during August 1964 are presented in table 3. The data are also represented in the beta activity isogram map of North America, figure 4.

TABLE 3.—GROSS BETA ACTIVITY OF AIRBORNE PARTICULATES, MEXICO, AUGUST 1964

[Concentrations in pc/m³]

Station	Number of Samples	Maximum	Minimum	Average
Acapulco	8	0.3	0.1	0.1
Ciudad Juárez	22	1.3	0.1	0.2
Chihuahua	22	1.3	0.1	0.3
Ensenada	4	0.5	0.4	—
Guadalajara	16	0.2	0.1	0.1
Guaymas	11	0.2	0.1	0.1
La Paz	17	0.5	0.1	0.2
Matamoros	15	0.5	0.1	0.2
Mazatlán	5	0.1	0.1	0.1
Mérida	6	0.3	0.1	0.2
México, D.F.	15	0.1	0.1	0.1
Nuevo Laredo	10	0.3	0.1	0.2
San Luis Potosí	5	0.5	0.1	0.2
Tampico	22	0.3	0.1	0.2
Torreón	26	0.4	0.1	0.2
Tuxtla Gutiérrez [a]				
Veracruz	16	0.5	0.1	0.2

[a] Temporarily shut down.

FIGURE 4.—FALLOUT NETWORK SAMPLING STATIONS IN MEXICO

4. Pan American Air Sampling Program August 1964

Pan American Health Organization and Public Health Service

Gross beta activity in air is monitored by four countries in the Americas under the auspices of a collaborative program developed by the Pan American Health Organization and the Public Health Service (PHS) for assisting countries of the Americas in developing radiological health programs. The sampling equipment and analytical services are provided by the Division of Radiological Health, PHS, and are identical with those employed for the Radiation Surveillance Network.

The four air sampling stations included in the program are operated by the technical staff of the Ministry of Health in each country. The station in Kingston, Jamica, is operated by the Public General Hospital; in Caracas, Venezuela, by the Venezuelan Institute for Scientific Investigations; in Lima, Peru, by the Institute of Occupational Health; and in Santiago, Chile, by the Occupational Health Service. The Kingston station began operation in March 1964, and the other three were started near the end of 1962.

The August 1964 air monitoring results from the four participating countries are given in table 4. The Caracas and Jamaica stations, included in figure 5 with the August averages adjusted by the RSN intercalibration factor,[3] were used in positioning the beta concentration isograms.

TABLE 4.—GROSS BETA ACTIVITY IN AIR, AUGUST 1964

[Concentrations in pc/m³]

Sampling stations	No. of samples	Maximum	Minimum	Average [a]
Kingston, Jamaica	14	0.60	<0.10	0.25
Caracas, Venezuela	21	0.19		0.11
Lima, Peru	21	0.17		0.10
Santiago, Chile	27	0.27		0.14

[a] The monthly average is calculated by weighting the individual samples with length of sampling period. Values of <0.10 are assumed to be 0.10 for averaging purposes. If the <0.10 values represent more than 10 percent of the average, a less-than sign is placed in front of the average.

[3] The RSN factor is 1.28.

5. Gross Beta Activity in Air, North America August 1964

Beginning with January 1963 data, monthly average concentrations of airborne gross beta activity in Canada and the United States have been presented in combined form as isogram maps of most of North America. The data from the Radiation Surveillance Network and the Canadian Air Network were adjusted to each other by means of an intercalibration factor derived by Lockhart and Patterson (*13*).

With the formation of the Mexican Air monitoring program, new intercalibration ratios were determined, this time including the Canadian Network, Radiation Surveillance Network, National Air Sampling Network, the HASL 80th Meridian Network, and the Mexican Network (*14*). The new intercalibration factors reflect some changes in standardization in both the RSN and the Canadian Air Network, effective September 1963.

Figure 5 shows the August 1964 activity in air throughout North America based on the data from the Canadian Air Monitoring Program, the Radiation Surveillance Network and Mexican Air Monitoring program. An intercalibration factor of 1.28 was applied to the RSN data and the Mexican data were multiplied by 0.81 in order to adjust them to Canadian data.

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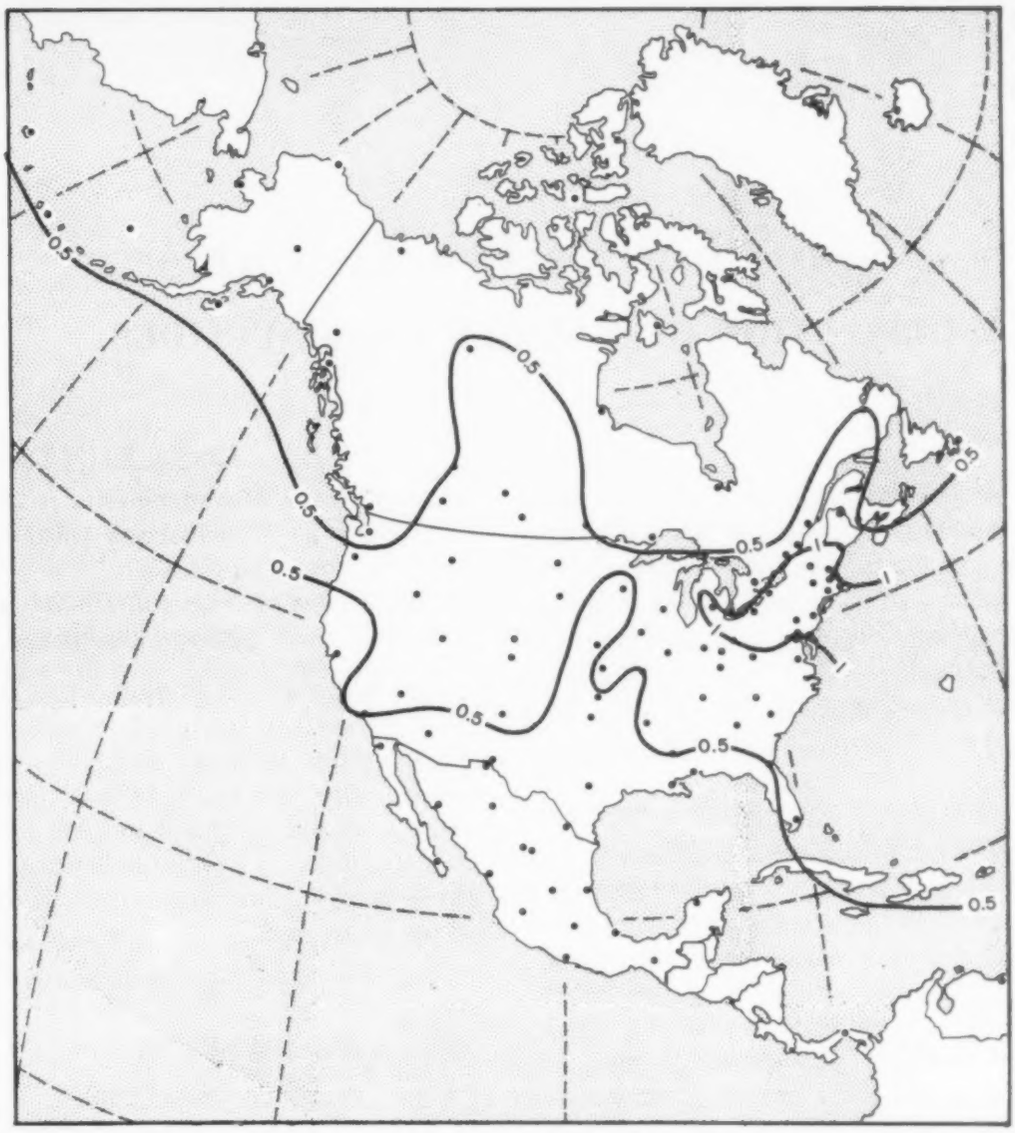

FIGURE 5.—ISOGRAM OF AVERAGE GROSS BETA CONCENTRATIONS IN AIR, NORTH AMERICA, AUGUST 1964

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MONTHLY DEPOSITION OF VARIOUS RADIONUCLIDES

For the purpose of this section the word "fallout" refers to the deposition of radioactive materials on the earth's surface, normally expressed in terms of the activity of selected radionuclides deposited on a unit surface during a given period of time. Unless otherwise stated, fallout measurements include both precipitation and dry fallout (settled dust).

Following are reports of fallout measurements at selected stations in Canada.

Fallout Measurements in Canada April–June 1964

Department of National Health and Welfare
Ottawa, Canada

The monthly accumulated precipitation samples collected in conjunction with the Canadian air sampling network described earlier in this issue represent total fallout (wet and dry), since they are collected in deep pots lined with polyethylene. The radiochemical analyses of these samples for April through June 1964 are given in table 1.

TABLE 1.—ANALYSIS OF FALLOUT FOR SPECIFIC RADIONUCLIDES, APRIL–JUNE 1964

[Deposition in nc/m²]

Station	April		May		June	
	Sr^{90}	Cs^{137}	Sr^{90}	Cs^{137}	Sr^{90}	Cs^{137}
Calgary	0.27	0.65	2.17	3.65	1.63	3.00
Coral Harbour	0.10	0.25	0.21	0.34	0.94	2.03
Edmonton	0.82	1.50	4.36	6.72	1.01	2.46
Ft. Churchill	0.32	0.46	1.34	1.80	1.39	2.22
Ft. William	3.85	5.55	5.84	9.65	5.10	8.05
Fredericton	1.95	3.30	0.29	1.42	1.84	4.41
Goose Bay	0.77	0.83	2.12	3.12	2.87	5.53
Halifax	1.75	3.36	1.36	2.28	1.63	2.79
Inuvik	0.10	0.20	0.24	0.41	1.76	2.06
Montreal	1.32	2.20	1.65	3.11	1.26	2.11
Moosonee	0.97	2.35	4.31	6.72	2.64	5.04
Ottawa	1.71	2.02	2.10	3.63	0.98	1.62
Quebec	1.50	2.48	1.46	3.46	2.66	5.17
Regina	0.36	0.76	1.54	2.54	2.87	5.38
Resolute	0.52	0.52	1.14	1.70	0.63	0.92
St. John's, Nfld	1.17	2.11	2.00	3.35	2.34	3.61
Saskatoon			1.74	3.19	1.57	2.80
Sault Ste. Marie	2.24	3.18	2.38	3.89	2.09	3.28
Toronto			1.70	3.10	0.61	1.02
Vancouver	1.11	1.91	3.05	4.66	1.49	2.25
Whitehorse	0.10	0.23	0.40	1.16	0.21	1.30
Windsor	2.76	5.20	1.11	2.03	2.96	5.16
Winnipeg	1.05	2.00	1.91	3.90	2.93	4.44
Yellowknife	0.18	0.31	0.70	1.24	0.59	1.10

Section II—Milk and Food

MILK SURVEILLANCE

Although milk is only one of the many sources of dietary intake of radionuclides, it is the single food item most often used as an indicator of the population's intake of radionuclides from the environment. This is because fresh milk is consumed by a large segment of the United States population and contains most of the radionuclides occurring in the environment which have been identified as biologically important. In addition, milk is produced and consumed on a regular basis, is convenient to handle, is easily analyzed, and samples which are representative of milk consumption in any area can be readily obtained.

1. Pasteurized Milk Network, August 1964

Division of Radiological Health and Division of Environmental Engineering and Food Protection, Public Health Service

The Public Health Service pasteurized milk surveillance program had its origin in a raw milk monitoring network (*1*) established by the Service in 1957. One of the primary objectives of the raw milk network was the development of methods for milk collection and radiochemical analysis suitable for larger scale programs.

Experience derived from this earlier network led to the activation of a pasteurized milk sampling program with stations selected to provide nationwide surveillance of milk production and consumption areas. The present network, which consists of 63 stations, has at least one station in every State, the Canal Zone, and Puerto Rico.

Sampling Procedure

Through the cooperation of State and local milk sanitation authorities, samples are routinely collected at each station. The method specifies that an individual station's sample be composited of subsamples from each milk processing plant in proportion to the plant's average sales in the community served. At most stations the sample represents from 80 to 100 percent of the milk processed. Prior to September 15, 1961, the composite sample was taken from one day's sales per month and was as representative of the community's supply as could be achieved under practical conditions. Beginning with the resumption of nuclear weapons testing in the atmosphere in September 1961, and continuing through January 1963, samples were collected twice a week at nearly all stations and daily for short periods at selected stations. Since then, the sampling frequency has been reduced to once a month.

Samples are preserved with formaldehyde and are sent to the PHS Southwestern (SWRHL), Southeastern (SERHL), or Northeastern Radiological Health Laboratories (NERHL) for analysis. Gamma analyses for iodine–131 are made within 3 to 6 days after sample collection, and any results exceeding 100 pc/liter are immediately telephoned to State health officials for possible public health action. Analytical results are normally available 6 to 7 weeks after monthly samples are received by the laboratories; publication in *RHD* follows 3 to 4 months after the monthly samples are composited for analyses.

Analytical Procedures

Iodine–131, cesium–137, and barium–140 concentrations are determined by gamma scintillation spectroscopy.[1] After the weekly samples are gamma scanned, samples from two consecutive weeks are composited and analyzed radiochemically for strontium–89 and strontium–90. There is an inherent statistical variation associated with all measurements of radionuclide concentrations. With the low radionuclide levels which are usually found in milk and other environmental samples, this variation on a percentage basis is relatively high. The variation depends upon such factors as the method of chemical analysis, the sample counting rate and counting time, interferences from other radionuclide and the background count. For milk samples, counting times of 50 minutes for gamma spectroscopy and 30 to 50 minutes for beta determinations are used. Table 1 shows the approximate total analytical error (including counting error) associated with radionuclide concentrations in milk. These errors were determined by comparing results of a large number of replicate analyses. Table 1 gives the 95 percent confidence limits between which the true concentrations of the selected radionuclides might be expected in the analyses. The minimum detectable concentration is defined as the measured concentration at which the two-standard-deviation analytical error is equal to the measurement. Accordingly, the minimum detectable concentrations in units of pc/liter are Sr^{89}, 5; Sr^{90}, 2; Cs^{137}, 10; Ba^{140}, 10; and I^{131}, 10. At these levels and below, the counting error comprises nearly all of the analytical error.

TABLE 1.—ANALYTICAL ERRORS ASSOCIATED WITH ESTIMATED CONCENTRATIONS FOR SELECTED RADIONUCLIDES IN MILK

Nuclide	Estimated concentration (pc/liter)	Error [a] (pc/liter)	Estimated concentration (pc/liter)	Error [a] (percent of concentration)
Iodine-131	0 to 100	±10	100 or greater	±10
Barium-140	0 to 100	±10	100 or greater	±10
Cesium-137	0 to 100	±10	100 or greater	±10
Strontium-89	0 to 50	±5	50 or greater	±10
Strontium-90	0 to 20	±2	20 or greater	±10

[a] Two standard deviations (2σ).

[1] Southeastern Radiological Health Laboratory employs a radiochemical procedure for barium–140 analysis.

Calcium analyses at SERHL are done by an ion exchange and permanganate titration method while at NERHL and SWRHL an ethylenediaminetetraacetic acid (EDTA) method is used. Stable potassium concentrations are estimated from the potassium–40 concentrations[2] determined from the gamma spectrum.

Data Presentation

Table 2 presents summaries of the analyses for August 1964 (July 26-August 29). Although not shown in table 2, the iodine–131 and barium–140 monthly average concentrations in milk were less than 10 pc/liter. Radionuclide values reported by a laboratory as being below the minimum detectable concentration have been averaged by using one-half the minimum detectable value. The averaging procedure was modified for iodine–131 and barium–140 in October 1963 when nondetectable concentrations of these radionuclides were considered zero. A similar procedure is used for the network average.

Figures 1 and 2 are isogram maps showing the estimated strontium–90 and cesium–137 concentrations in milk over the entire country. The value printed beside each station is the monthly average concentration for that station. The isograms were developed by arbitrary interpolation between values for the individual stations. Additional modifications to the isograms are made according to available information on milksheds.

In order to develop the distribution of the network's stations *versus* radionuclide concentrations in milk, tables 3 and 4 have been prepared using monthly averages.

The average monthly strontium–90 concentrations in pasteurized milk from selected cities in the sampling program are presented in figure 3. The data regarding reported nuclear detonations given in this figure are presented for information only. The underground nuclear detonations during 1963 and 1964 are not intended to imply a cause and effect relationship with the rising strontium levels during this period. Each graph shows the strontium–90 concentrations in milk from one city in each of the four U.S. Bureau of Census regions. This method of selection permits graphic presentation of data for each city in the network three

[2] The conversion factor is 1.18×10^{-3} g K/pc K^{40}.

TABLE 2.—STABLE ELEMENT AND RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, AUGUST 1964 [a]

[Average radioactivity concentrations in pc/liter]

Sampling locations		Calcium (g/liter)		Potassium (g/liter)		Strontium-89		Strontium-90		Cesium-137		Last Sr^{90} graph in *RHD* (1964)
		Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	Second quarter	Avg. for month	
Ala:	Montgomery	1.15	1.17	1.5	1.4	<5	<5	26	22	90	70	Oct
Alaska:	Palmer	1.22	1.17	1.4	1.4	5	<5	25	13	150	100	Nov
Ariz:	Phoenix	1.17	1.14	1.5	1.3	<5	<5	6	4	30	25	Sep
Ark:	Little Rock	1.15	1.14	1.5	1.6	<5	<5	58	39	160	80	Nov
Calif:	Sacramento	1.24	1.27	1.5	1.3	<5	<5	9	5	50	25	Dec
	San Francisco	1.22	1.18	1.4	1.3	<5	<5	12	9	55	30	Oct
Canal Zone:	Cristobal	1.09	1.11	1.5	1.6	<5	<5	6	4	55	50	Nov
Colo:	Denver	1.22	1.25	1.5	1.4	<5	5	22	17	90	100	Dec
Conn:	Hartford	1.14	1.11	1.5	1.6	<5	<5	23	20	160	115	Dec
Del:	Wilmington	1.20	1.12	1.5	1.5	<5	<5	30	19	145	85	Sep
D. C:	Washington	1.12	1.12	1.6	1.6	<5	<5	23	18	100	60	Oct
Fla:	Tampa	1.13	1.18	1.5	1.5	<5	<5	15	15	260	255	Sep
Ga:	Atlanta	1.15	1.16	1.5	1.5	<5	<5	36	29	165	105	Oct
Hawaii:	Honolulu	1.16	1.19	1.6	1.3	<5	<5	11	15	85	75	Nov
Idaho:	Idaho Falls	1.21	1.22	1.4	1.2	10	<5	34	26	205	105	Sep
Ill:	Chicago	1.16	1.11	1.5	1.5	<5	<5	19	20	130	85	Oct
Ind:	Indianapolis	1.20	1.17	1.5	1.5	<5	<5	25	16	110	65	Dec
Iowa:	Des Moines	1.22	1.20	1.4	1.3	5	<5	30	20	100	65	Sep
Kans:	Wichita	1.19	1.17	1.4	1.3	5	<5	25	16	80	50	Nov
Ky:	Louisville	1.13	1.12	1.5	1.6	<5	<5	37	27	100	50	Sep
La:	New Orleans	1.18	1.19	1.5	1.6	<5	<5	59	49	180	115	Nov
Maine:	Portland	1.18	1.15	1.5	1.5	<5	<5	33	26	210	180	Sep
Md:	Baltimore	1.13	1.12	1.5	1.5	<5	<5	28	20	125	60	Sep
Mass:	Boston	1.18	1.14	1.6	1.5	<5	<5	38	30	245	195	Oct
Mich:	Detroit	1.17	1.12	1.5	1.5	<5	<5	21	15	120	90	Dec
	Grand Rapids	1.22	1.16	1.5	1.5	<5	<5	23	18	135	100	Sep
Minn:	Minneapolis	1.22	1.21	1.5	1.4	10	<5	37	26	160	110	Oct
Miss:	Jackson	1.22	1.19	1.5	1.5	<5	<5	53	38	125	90	Dec
Mo:	Kansas City	1.19	1.16	1.4	1.3	10	<5	32	24	100	50	Dec
	St. Louis	1.21	1.22	1.4	1.3	10	<5	28	17	95	55	Nov
Mont:	Helena	1.19	1.22	1.5	1.5	5	<5	32	19	195	100	Nov
Nebr:	Omaha	1.21	1.24	1.5	1.4	5	<5	30	22	105	75	Sep
Nev:	Las Vegas	1.20	1.18	1.5	1.3	<5	<5	10	7	90	50	Oct
N. H:	Manchester	1.19	1.15	1.5	1.5	<5	<5	33	28	250	200	Sep
N. J:	Trenton	1.16	1.11	1.5	1.5	<5	<5	23	16	135	90	Dec
N. Mex:	Albuquerque	1.19	1.19	1.5	1.4	5	<5	14	7	70	45	Nov
N. Y:	Buffalo	1.15	1.08	1.5	1.5	<5	<5	24	17	160	105	Dec
	New York	1.14	1.11	1.5	1.5	<5	<5	30	23	180	120	Oct
	Syracuse	1.16	1.12	1.6	1.5	<5	<5	23	15	160	85	Nov
N. C:	Charlotte	1.16	1.16	1.5	1.5	<5	<5	43	39	140	105	Nov
N. Dak:	Minot	1.20	1.23	1.5	1.4	15	10	72	44	175	125	Sep
Ohio:	Cincinnati	1.18	1.16	1.5	1.5	<5	<5	28	17	105	60	Dec
	Cleveland	1.18	1.12	1.5	1.5	<5	<5	25	18	135	80	Nov
Okla:	Oklahoma City	1.13	1.12	1.6	1.6	<5	<5	27	18	75	50	Oct
Ore:	Portland	1.26	1.24	1.4	1.4	10	<5	40	28	190	175	Dec
Pa:	Philadelphia	1.17	1.11	1.5	1.5	<5	<5	25	17	140	75	Nov
	Pittsburgh	1.18	1.12	1.5	1.5	<5	<5	34	29	175	115	Nov
P. R:	San Juan	1.11	1.14	1.5	1.7	<5	<5	15	10	90	70	Nov
R. I:	Providence	1.17	1.13	1.5	1.5	<5	<5	27	21	180	140	Sep
S. C:	Charleston	1.16	1.16	1.5	1.6	<5	<5	35	34	145	120	Dec
S. Dak:	Rapid City	1.14	1.24	1.5	1.3	10	<5	48	40	155	105	Oct
Tenn:	Chattanooga	1.17	1.22	1.4	1.5	<5	<5	51	40	145	95	Oct
	Memphis	1.16	1.18	1.5	1.6	<5	<5	42	31	85	55	Sep
Tex:	Austin	1.11	1.12	1.6	1.6	<5	<5	10	8	45	30	Oct
	Dallas	1.12	1.16	1.5	1.6	<5	<5	22	17	70	45	Dec
Utah:	Salt Lake City	1.24	1.31	1.5	1.5	10	<5	30	23	195	175	Nov
Vt:	Burlington	1.18	1.10	1.5	1.5	<5	<5	30	25	190	155	Dec
Va:	Norfolk	1.13	1.13	1.5	1.5	<5	<5	28	24	110	70	Dec
Wash:	Seattle	1.21	1.24	1.5	1.3	10	<5	36	28	190	170	Oct
	Spokane	1.27	1.24	1.5	1.4	10	<5	29	24	155	130	Dec
W. Va:	Charleston	1.13	1.14	1.5	1.4	<5	<5	34	24	95	55	Oct
Wis:	Milwaukee	1.23	1.18	1.6	1.6	<5	<5	21	14	145	90	Sep
Wyo:	Laramie	1.22	1.16	1.4	1.3	15	<5	25	18	120	105	Sep
Network average		1.18	1.17	1.5	1.5	<5	<5	28.9	21.6	133	94	Nov

[a] The monthly average iodine-131 and barium-140 concentration at each station was <10 pc/liter.

times a year. The last column in table 2 shows the most recent issue in which a graph of the strontium–90 concentration was given for each station. A tabulation of the network monthly maximum, minimum, and average radionuclide concentrations in milk was given for March 1960—March 1964 in the July 1964 issue of *RHD* (*2*).

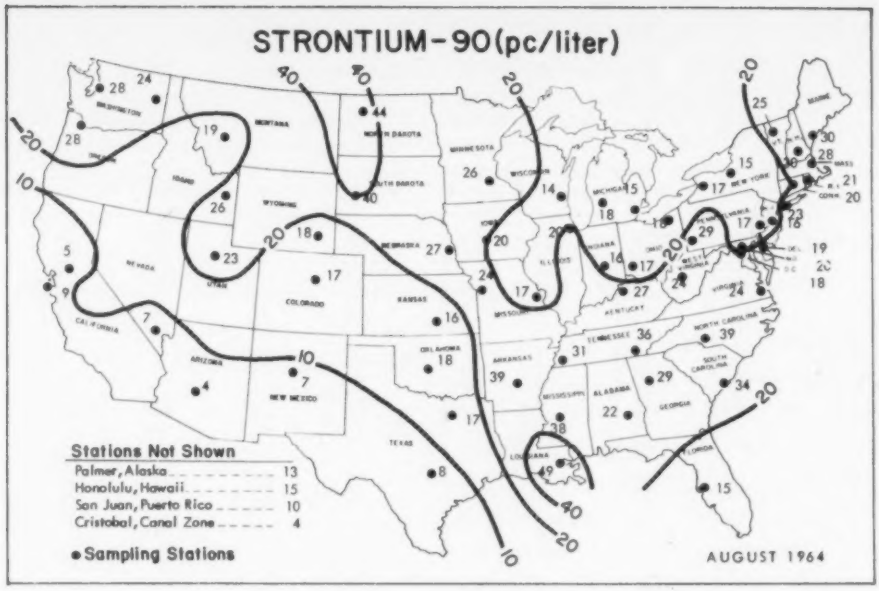

FIGURE 1.—STRONTIUM-90 CONCENTRATIONS IN PASTEURIZED MILK

TABLE 3.—STATION MONTHLY AVERAGES FOR STRONTIUM-90 MARCH-AUGUST 1964

Range (pc/liter)	Number of stations in range (1964)					
	Mar.	Apr.	May	June	July	Aug.
Under 10	2	4	3	4	6	7
10–19	17	12	8	6	6	23
20–29	30	28	20	23	29	23
30–39	10	12	20	17	14	6
40–49	2	2	6	10	4	4
50–59	1	2	4	2	1	0
60–69	1	3	1	0	2	0
70–79	0	0	1	1	0	0

TABLE 4.—STATION MONTHLY AVERAGES FOR CESIUM-137 MARCH-AUGUST 1964

Range (pc/liter)	Number of stations in range (1964)					
	Mar.	Apr.	May	June	July	Aug.
Under 50	2	2	2	1	4	6
50–99	11	12	16	19	24	30
100–149	22	23	17	24	21	19
150–199	20	17	23	13	8	6
200–249	6	7	3	4	3	1
250–299	2	2	2	2	2	1
300–349	0	0	0	0	0	0
350–399	0	0	0	0	0	0

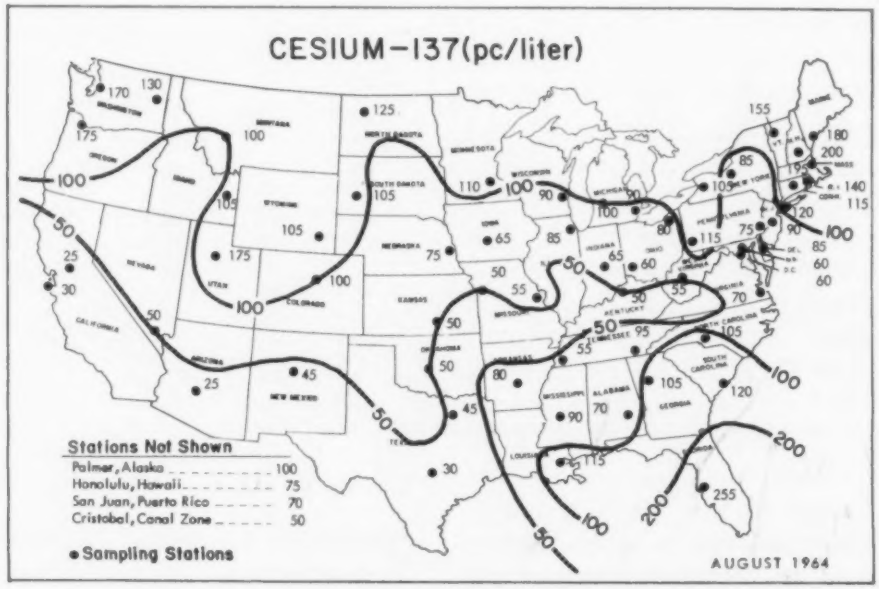

FIGURE 2.—CESIUM-137 CONCENTRATIONS IN PASTEURIZED MILK

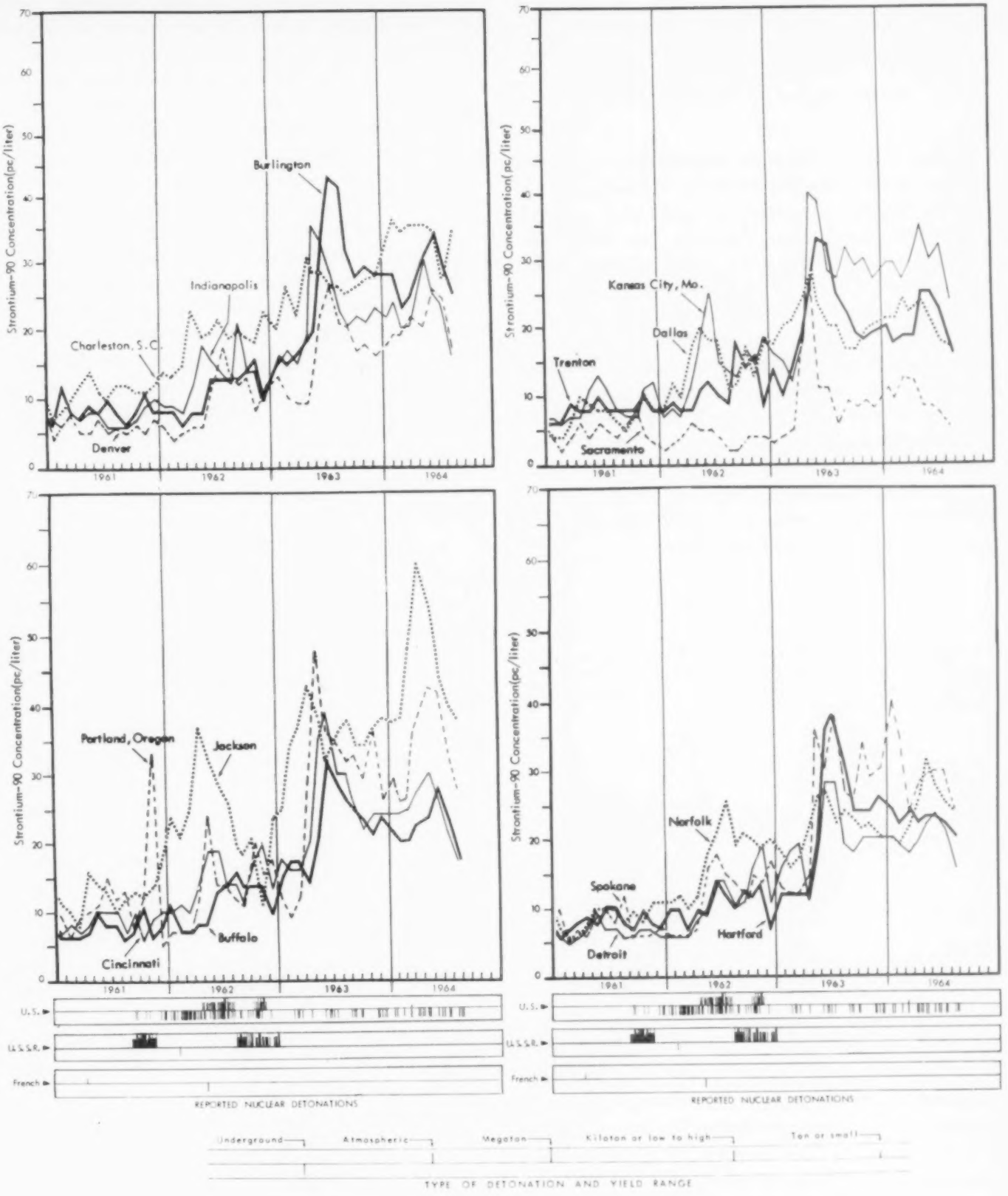

FIGURE 3.—STRONTIUM-90 IN PASTEURIZED MILK, 1961—AUGUST 1964

752—783—64—2

2. California Milk Network[3] April-June 1964

State of California
Department of Public Health

Surveillance of specific radionuclides in milk is one phase of California's Department of Public Health program of radiation control. This milk monitoring function has been conducted at 8 milksheds since January 1960 by the Department's Bureau of Radiological Health, a constituent of the Division of Environmental Sanitation. Since the addition of the Del Norte and Mendocino milksheds to the program in March 1962, sampling of pasteurized milk weekly or biweekly has been conducted at 10 major milksheds (see figure 4). The original sampling locations were chosen by the State Department of Agriculture as being representative of milk consumed by a high percentage of the population of the State.

[3] Data from *Radiological Health News Vol. 3*, No. 4, Bureau of Radiological Health, State of California Department of Public Health, 2151 Berkeley Way, Berkeley 4, California.

Analytical Procedures

After precipitation of the proteins with trichloroacetic acid, yttrium–90 is separated and beta counted, and total radiostrontium remaining in the filtrate is determined by beta counting in a low background counter, usually for a 60-minute period. Strontium–90 is determined from the yttrium–90 results; strontium–89 is determined by difference.

Potassium–40, iodine–131, cesium–137 and barium–140 in whole fluid milk are determined by gamma scintillation spectroscopy using a sodium-iodide crystal. A normal counting time of 100 minutes is used. The stable potassium content of milk (g/liter) may be estimated by multiplying the potassium–40 concentration (pc/liter) by 1.18×10^{-3}. A more complete description of the laboratory equipment and procedures has been published in the February 1963 issue of *Radiological Health Data* (*3*).

Results

The monthly averages of the radionuclide and calicum data for milk for the period April-June 1964 are presented in table 5. Background information of the differences among the California milksheds was presented by Heslep and Cornish in the December 1963 issue of *RHD* (*4*).

FIGURE 4.—CALIFORNIA MILKSHEDS

TABLE 5.—RADIONUCLIDES IN CALIFORNIA MILK, APRIL–JUNE 1964[a]

[Radioactivity concentrations in pc/liter]

Element and month	Del Norte	Fresno	Humboldt	Los Angeles	Mendocino	Sacramento	San Diego	Santa Clara	Shasta	Sonoma	Average
Calcium (g/liter)											
April	1.36	1.19	1.05	1.16	1.25	1.18	1.20	1.17	1.18	1.24	1.20
May	1.48	1.18	1.26	1.11	1.21	1.21	1.16	1.22	1.18	1.23	1.22
June	1.34	1.18	1.23	1.08	1.15	1.11	1.12	1.16	1.12	1.16	1.17
Potassium-40											
April	1,290	1,255	1,090	1,255	1,275	1,300	1,230	1,320	1,265	1,265	1,255
May	1,290	1,250	1,156	1,235	1,265	1,233	1,250	1,310	1,165	1,270	1,242
June	1,260	1,260	1,180	1,220	1,350	1,280	1,235	1,270	1,235	1,260	1,255
Strontium-89											
April	3.3	0.8	4.0	0.4	2.7	0.9	[b] 0	1.4	2.8	2.8	1.9
May	[b] 0	0	0	0	0	0.8	0	0.3	5.5	0	0.7
June	14.0	0	0	0	0	0	0	0	0	0	1.4
Strontium-90											
April	115.8	6.3	27.5	6.8	15.3	12.4	5.4	4.5	12.8	10.9	21.8
May	77.6	5.0	22.8	4.1	17.2	8.3	7.1	5.9	10.6	9.4	16.8
June	60.9	10.2	17.6	4.2	11.3	11.1	5.3	7.0	10.7	9.8	14.8
Cesium-137											
April	189	40.2	72.2	38.1	38.1	43.6	24.0	37.5	63.9	40.2	58.7
May	166	37.8	59.0	41.6	30.4	38.2	31.3	39.5	46.7	33.0	52.4
June	206	37.8	78.9	33.1	30.0	49.9	19.7	42.4	59.5	40.2	59.8

[a] No significant amounts of iodine-131 or barium-lanthanum-140 in samples for this period were found.
[b] A zero indicates activity less than twice the counting error at the 95 percent confidence level.

3. Florida Milk Network January-March 1964

Division of Radiological and Occupational Health
Florida State Board of Health

The Florida State Board of Health began sampling raw milk for iodine–131 analysis in two major areas of the State in November 1962. The program has since been expanded to include the analysis of milk for strontium–89, strontium–90 and cesium–137. Raw milk samples are received from the six areas shown in figure 5. Samples for iodine–131 analysis are taken from a tank truck, the route of which passes by farms widely dispersed over the area represented. Where there is no route representative of a large portion of the area, samples are collected from selected farms and combined. Samples were collected weekly when iodine–131 was detectable in milk. Presently, the sampling is on a monthly basis.

FIGURE 5.—FLORIDA MILK SAMPLING LOCATIONS

A regional State Board of Health Laboratory is located in each of these areas shown in figure 5. For strontium–89, strontium–90 and cesium–137 analysis monthly composite raw milk samples are prepared by each regional laboratory from samples routinely submitted. The composite sample is a size-stratified random sample obtained by numbering farms and using a table of random numbers. Each size stratum contributes to the total volume of the sample in proportion to the number of cows in that stratum. Ten percent of the farms in each stratum is selected for compositing. These composite samples are then sent to the State Radiological Health Laboratory in Orlando for analysis.

TABLE 6.—RADIONUCLIDES IN FLORIDA MILK, JANUARY–MARCH 1964[a]

[Concentrations in pc/liter]

Sampling location	Strontium-89			Strontium-90			Cesium-137		
	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.	Jan.	Feb.	Mar.
West	<5	5	<5	17	10	13	191	192	232
North	<5	<5	<5	16	11	14	170	203	175
Northeast	<5	<5	<5	15	10	11	159	196	181
Central	<5	<5	<5	10	11	12	211	244	309
Tampa Bay Area	<5	<5	<5	8	13	10	176	198	234
Southeast	<5	<5	<5	12	10	15	201	200	234
Average	<5	<5	<5	13	11	13	185	206	228

[a] All iodine-131 concentrations during this period were <2 pc/liter.

Milk produced in the counties comprising each area is generally processed, marketed, and consumed in that area. These areas are characterized by differences in dairying practices related to the gradual transition from small farms—using locally grown feeds in the "West Florida" region—to larger farms using different types of grass and predominantly purchased feeds in the southern areas.

Analytical Procedures

Strontium–89 and strontium–90 concentrations in milk samples are determined by radiochemical separations and beta counting in a low background counter. Cesium–137 and iodine–131 content is determined by gamma scanning with a 512-channel analyzer.

Results and Discussion

Table 6 presents all available monthly average strontium–90, strontium–89, and cesium–137 concentrations in Florida milk for January-March 1964. Iodine–131 results for 1963 appeared in the March 1964 issue of *RHD* (*5*).

Comparison of the Public Health Service Pasteurized Milk Network data for Tampa, Florida, for 1963 (May 1963-April 1964 issues of *RHD*) with the results from the Florida State Board of Health's Tampa Bay Area gives an indication of the agreement of the two sampling methods:

1. raw milk composites from a sampling of farms and
2. pasteurized milk composites from processing plants.

These two sampling techniques provide estimates of the yearly average strontium–90 concentrations in raw and pasteurized milk that are within 38 percent of each other. Yearly average strontium–89 concentrations in raw and pasteurized milk have been within 14 percent of each other. For cesium–137 concentrations, the two methods gave average results within 15 percent of each other for April-December 1963 when analyses were being done.

4. Indiana Milk Network
August 1964

Bureau of Environmental Sanitation
Indiana State Board of Health

The Indiana State Board of Health began sampling pasteurized milk for radiological analysis in September 1961. Indiana was geographically divided into five major milksheds, and one large dairy within each milkshed was selected as a sampling station (figure 6).

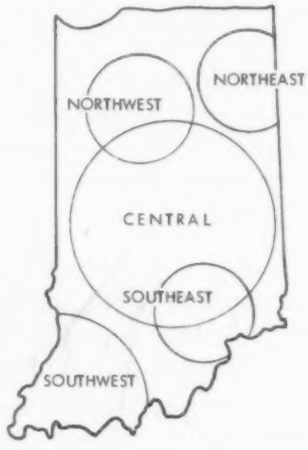

FIGURE 6.—INDIANA MILK SAMPLING LOCATIONS

The milk samples are routinely analyzed for iodine–131, cesium–137, barium–140, strontium–89 and strontium–90. Until August 1963, analyses for the gamma emitters iodine–131, cesium–137 and barium–140 were conducted on a weekly basis, except when iodine–131 exceeded 100 pc/liter, at which times the frequency of sampling was increased. Because of continued low concentrations of the short-lived gamma emitters, the sampling frequency was reduced in August 1963 to once per month for the northeast, southeast and southwest milksheds. Strontium–89 and strontium–90 analyses are performed monthly for each station.

An ion exchange analytical procedure (*6*) is employed for strontium–89 and strontium–90 analyses. Minimum detectable levels for strontium–89 and strontium–90 are about 5 and 1 pc/liter, respectively. A 512-channel pulse height analyzer and shielded 4 x 4-inch sodium iodide crystal are used for the gamma analysis of iodine–131, cesium–137, and barium–140. Analyses of counting statistics indicate that the lower limit of detectability for both iodine–131 and barium–140 is 5 pc/liter. Cesium–137 analyses are subject to a 6 percent error at the 100 pc/liter level. Additional factors such as drift of the analyzer and calibration factors will increase these limits to some extent.

The monthly averages of the data obtained for the individual sampling stations and the State averages are reported in table 7.

TABLE 7.—RADIONUCLIDES IN INDIANA MILK, AUGUST 1964 [a]

[Radionuclide concentrations in pc/liter]

Sampling location	Calcium (g/liter)	Potassium-40	Strontium-90	Cesium-137
Northeast	1.20	1,280	16	70
Southeast	1.20	1,310	16	55
Central	1.20	1,330	17	60
Southwest	1.18	1,290	19	50
Northwest	1.18	1,310	15	75
State average	1.19	1,300	17	60

[a] The monthly average iodine-131, barium-140, and strontium-89 concentrations at each station were zero.

5. New York Milk Network
June 1964

Division of Environmental Health Services
State of New York Department of Health

Milk samples collected routinely from six cities—Albany, Buffalo, Massena, Newburgh, New York City, and Syracuse (figure 7) are analyzed for their radionuclide content by the State of New York Department of Health. Pasteurized milk samples are collected daily and composited weekly for the determination of strontium–89, strontium–90, iodine–131, cesium–137 and barium-lanthanum–140 at all stations except Massena, where samples are composited bi-weekly, and at New York City where one daily milk sample representing the total milk supply for that day is obtained and analyzed once per week. Samples are obtained from processing plants except at Albany, where the daily sample is obtained from a marketing point. During periods when cows are no longer on stored feed, the sample from Albany is analyzed daily for iodine–131. In the event that any city reports iodine–131 concentrations exceeding 100 pc/liter, increased surveillance is undertaken.

FIGURE 7.—NEW YORK MILK SAMPLING LOCATIONS

A matrix method (*7*) is used for the analysis of spectral data to determine the concentrations of gamma-emitting nuclides in milk. With this method, the individual nuclide contributions to the gamma spectrum are separated by solution of simultaneous equations describing the spectral interferences.

The analytical procedure for strontium–89 and strontium–90 is based on ion exchange methods. Cations (including radiostrontium) are eluted from the ion exchange resin with sodium chloride solution, strontium isotopes are gathered by means of sodium carbonate, isolated by means of ethylenediaminetetraacetic acid (EDTA), and radiostrontium is counted with a low background beta counter having an 0.8 mg/cm^2 window. The strontium–90 portion is differentially estimated by a second count 40 hours later to determine the rate of in-growth of its daughter product yttrium–90. The monthly average radionuclide concentrations in milk are shown in table 8.

TABLE 8.—RADIONUCLIDES IN NEW YORK MILK, JUNE 1964 [a]

[Average concentrations in pc/liter]

Sampling location	Strontium-89	Strontium-90	Cesium-137
Albany	<3	20	86
Buffalo	3	20	103
Massena	<3	33	198
Newburgh	5	26	111
New York City	<3	28	129
Syracuse	4	19	89
Average	3	24	119

[a] The monthly average I^{131} and $Ba\text{-}La^{140}$ (in equilibrium) at each station were less than the minimum detectable levels (20 pc/liter).

6. Canadian Milk Network,[3] August 1964

Radiation Protection Division
Department of National Health and Welfare,
Ottawa, Canada

The Radiation Protection Division of the Department of National Health and Welfare began monitoring milk for strontium–90 in November 1955. At first analyses were carried out on samples of powdered milk obtained from processing plants. However, since January 1963 liquid whole milk has been analyzed instead. With this change, more representative samples of milk consumed can be obtained, and in addition it is possible to choose milk sampling locations (see figure 8) in the same areas as the air and precipitation stations. At present, the analyses include determinations of iodine–131, strontium–89, cesium–137, and strontium–90 as well as stable potassium and calcium.

The milk samples are obtained through the cooperation of the Marketing Division of the Canadian Department of Agriculture. At each station samples are collected three times a week from selected dairies and are combined into weekly composites and forwarded to the radiochemical laboratory in Ottawa. The contribution of each dairy to the composite sample is directly proportional to its volume of sales. In most cases a complete sample represents over 80 percent of the milk processed and distributed in the area. Several of the weekly samples are randomly selected and analyzed for iodine–131. The results of the spot checks for iodine–131 will not be reported unless there is evidence that the levels are rising. A monthly composite of the samples is analyzed for strontium–90, cesium–137, and stable potassium and calcium.

Analytical Methods

Radiochemical methods are used for the analysis of iodine–131 (*8*). For the analysis of radiostrontium, carrier strontium is added to a one-liter sample of milk, and the milk is then placed in a tray lined with a polyethylene sheet and evaporated under infra-red lamps. The residue is ashed in a muffle furnace at 450° C, dissolved in dilute nitric acid, and strontium separated by fuming nitric acid precipitation. The combined strontium–89 and strontium–90 are determined by counting in a low background beta counter. Strontium–90 is determined separately by extracting and counting its

[3] Data from *Radiation Protection Programs, Vol. 2, No. 9:* 25–30, Radiation Protection Division, Canadian Department of National Health and Welfare (Sept. 1964).

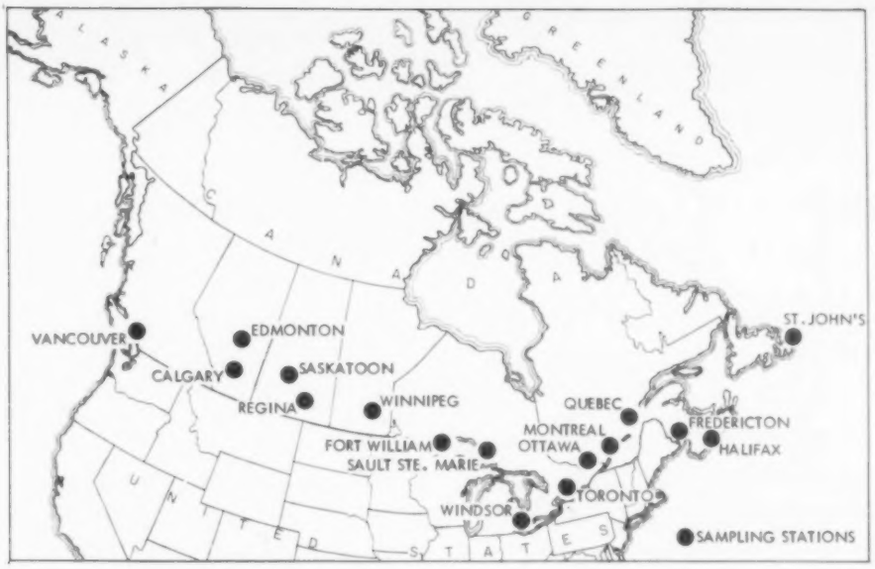

FIGURE 8.—CANADIAN MILK SAMPLING STATIONS

yttrium–90 daughter, while strontium–89 is estimated by difference from the total radiostrontium measurement. Appropriate corrections are made for self-absorption and counter efficiency at all stages. Calcium is determined by flame photometry.

Cesium–137 is determined by gamma spectroscopy using a scintillation crystal and a multi-channel pulse height analyzer. A sample consisting of 4.5 liters of milk is placed in a sample tray constructed in the form of an inverted well to accommodate the 5- x 4-inch sodium iodide crystal detector. The sample is counted for 100 minutes and the gamma spectrum recorded. Estimates are made of the potassium–40 and cesium–137 content of the milk by comparison of the spectrum with the spectra of standard preparations of these two radionuclides. With this method the potassium–40 concentration is determined and the Compton contribution of this radionuclide to the cesium–137 photopeak is subtracted to obtain the cesium–137 concentration. The stable potassium content is estimated from the potassium–40 concentration.

Sources of Error

In the iodine and strontium determinations, tests indicate that the statistical error (95 percent confidence level) in the chemical operations involved is about plus-or-minus 10 percent. This value is independent of the concentration of the radioisotope in the milk because it depends only on the recovery of the carrier. In the determination of cesium–137 this factor is not involved.

The chemical procedures error must be combined with the counting error which depends primarily on the concentration of the nuclide in the sample, the background radiation, and the length of time the sample and background are counted. This counting error has been evaluated mathematically for the particular counting arrangement used.

The overall errors, estimated on the basis indicated above, are given in table 9.

TABLE 9.—TOTAL ERROR FOR VARIOUS RADIONUCLIDE CONCENTRATIONS IN MILK[a]

Nuclide	Error for 10 pc/liter	Error for 50 pc/liter	Error for 100 pc/liter
Strontium-89	±25%	±20%	±15%
Strontium-90	±15%	±10%	±10%
Iodine-131	±50%	±20%	±10%
Cesium-137	±60%	±25%	±10%

[a] All errors are 2σ values, representing 95 percent confidence levels.

Results

Table 10 presents monthly averages of strontium–90, cesium–137 and stable calcium and potassium in Canadian whole milk. Spot checks for iodine–131 and strontium–89 indicate that all samples had <5 pc/liter.

TABLE 10.—RADIONUCLIDES IN CANADIAN WHOLE MILK, AUGUST 1964

[Radionuclide concentration in pc/liter]

Station	Calcium (g/liter)	Potassium (g/liter)	Strontium-90	Cesium-137
Calgary	1.14	1.5	26.3	119
Edmonton	1.12	1.5	26.6	133
Ft. William	1.09	1.5	36.1	200
Fredericton	1.12	1.6	44.2	245
Halifax	1.12	1.7	47.2	272
Montreal	1.09	1.7	22.4	134
Ottawa	1.08	1.6	19.4	118
Quebec	1.08	1.7	39.6	207
Regina	1.08	1.6	29.7	120
St. John's, Nfld	1.14	1.6	74.8	376
Saskatoon	1.12	1.6	29.9	119
Sault Ste. Marie	1.08	1.5	32.7	191
Toronto	1.08	1.6	11.6	94
Vancouver	1.12	1.6	39.1	286
Windsor	1.08	1.6	14.0	67
Winnipeg	1.09	1.6	25.6	122
Average	1.10	1.6	32.5	175

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(*2*) Public Health Service: Milk Surveillance, Pasteurized Milk Network, March 1964, *Radiological Health Data, 5:* 309–17 (July 1964).

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(*4*) Heslep, J. M. and A. C. Cornish: California Milk Network and Milkshed Comparisons, April-June 1963, *Radiological Health Data, 4:* 596–9 (December 1963).

(*5*) Division of Radiological and Occupation Health, Florida State Board of Health: Florida Milk Network, *Radiological Health Data, 5:* 121–22 (March 1964).

(*6*) Porter, C., D. Cahill, R. Schneider, P. Robbins, W. Perry, and B. Kahn: Determination of Strontium–90 in Milk by an Ion Exchange Method, *Analytical Chemistry, 33:* 1306–8 (September 1961).

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MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN PASTEURIZED MILK, SEPTEMBER 1963–AUGUST 1964

Division of Radiological Health, Public Health Service

Radionuclide concentration values reported by the Pasteurized Milk Network (*1*) can be used to estimate the contribution of milk to a population's radiation exposure. This is done by determining both the annual average concentrations of specific radionuclides in milk and the average daily milk consumption of a representative individual in a suitable sample of the population.

The data listed in table 1 are concerned with the first of these requirements, *i.e.*, annual average concentrations of strontium–89, strontium–90, and cesium–137 in one liter of pasteurized milk. Limited data are available for estimating the average daily milk consumption (on a volume basis) for specific age groups in the U.S. population (*2, 3*).

To arrive at a basis of comparison between the daily rates of intake of the radionuclides from the milk component of the diet and the Federal Radiation Council's ranges of transient daily rates of intake (*4*), it is assumed that the average daily milk consumption of an individual in a population group is one liter. The Guides, however, apply to total intake from all sources. The upper limits of Range II correspond to the Radiation Protection Guide (RPG) for iodine–131 and to one-third of the RPG for radioactive strontium. The Guides are, for administrative reasons, expressed as a yearly radiation dose, but are based on lifetime exposure (*5*). The FRC emphasizes that the annual acceptable risk or exposure dose is not a dividing line between safety and danger in actual radiation situations (*6*).

Annual averages of radionuclide concentrations in milk sampled by the PHS Pasteurized Milk Network are presented in table 1. The data in table 1 are calculated as follows: Results from all samples collected in each week (Sunday through Saturday) are averaged, and the averages for all weeks terminating in each of twelve consecutive months are averaged to obtain the annual average.[1] To obtain the annual average daily intake (pc/day) of radionuclides from milk, the annual average concentration values (pc/liter) in table 1 must be multiplied by the annual average daily consumption (liters/day) of milk.

Monthly variations of radionuclide concentrations in milk are influenced by a number of combined causes such as weather conditions and dairying practices. The moving yearly average (table 1), obtained by updating the previous twelve-month average by one month, shows variations averaged over the year and tends to minimize purely seasonal variations. This method, therefore, shows trends over a considerable period of time.

[1] Beginning with the October 1963 data, iodine–131 values of <10 pc/liter are considered to be zero for averaging purposes; previously, 5 pc/liter was used for calculating the averages.

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(*2*) Bureau of the Census, and Public Health Service: National Food Consumption Survey, Fresh Whole Milk Consumption in the United States, July 1962, *Radiological Health Data 4:* 15–17 (January 1963).

(*3*) Bureau of the Census and Public Health Service: Consumption of Selected Food Items in U. S. Households, July 1962, *Radiological Health Data, 4:* 124–7.

(*4*) Federal Radiation Council: Radiation Protection Guidance for Federal Agencies, *Federal Register: 9957–8*, Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (September 26, 1961).

TABLE 1.—MOVING ANNUAL AVERAGE RADIONUCLIDE CONCENTRATIONS IN MILK[a,b]

[Concentrations in pc/liter]

Sampling locations		Strontium-89		Strontium-90		Cesium-137	
		Aug 1963–July 1964	Sept 1963–Aug 1964	Aug 1963–July 1964	Sept 1963–Aug 1964	August 1963–July 1964	Sept 1963–Aug 1964
Ala:	Montgomery	10	5	23	23	89	87
Alaska:	Palmer	16	12	26	25	164	154
Ariz:	Phoenix	3	3	4	4	26	26
Ark:	Little Rock	21	9	46	45	157	141
Calif:	Sacramento	4	3	9	9	55	53
	San Francisco	6	5	10	10	63	60
Colo:	Denver	10	8	20	19	93	93
Conn:	Hartford	10	6	24	23	173	162
Del:	Wilmington	9	5	26	25	140	134
D. C:	Washington	9	6	20	20	94	90
Fla:	Tampa	7	4	15	15	246	245
Ga:	Atlanta	15	8	33	32	149	142
Hawaii:	Honolulu	5	4	11	11	82	82
Idaho:	Idaho Falls	18	14	29	28	183	179
Ill:	Chicago	7	5	21	20	124	121
Ind:	Indianapolis	9	5	23	22	108	102
Iowa:	Des Moines	13	10	27	26	98	96
Kans:	Wichita	9	7	22	21	72	71
Ky:	Louisville	19	10	34	32	106	97
La:	New Orleans	16	9	50	51	157	152
Maine:	Portland	14	8	34	33	233	219
Md:	Baltimore	12	7	23	23	116	107
Mass:	Boston	16	9	37	36	265	247
Mich:	Detroit	8	5	20	20	126	121
	Grand Rapids	9	5	22	22	136	132
Minn:	Minneapolis	19	14	35	34	163	158
Miss:	Jackson	16	9	42	42	116	112
Mo:	Kansas City	15	12	30	29	89	86
	St. Louis	11	9	24	24	90	87
Mont:	Helena	16	10	31	29	205	190
Nebr:	Omaha	14	11	28	27	102	101
Nev:	Las Vegas	8	7	11	11	83	81
N. H:	Manchester	14	8	35	34	276	259
N. J:	Trenton	9	6	21	20	130	123
N. Mex:	Albuquerque	6	4	12	12	56	56
N. Y:	Buffalo	9	6	23	22	159	152
	New York	13	8	31	29	190	176
	Syracuse	11	7	24	22	161	152
N. C:	Charlotte	15	8	35	36	123	119
N. Dak:	Minot	24	16	61	60	162	159
Ohio:	Cincinnati	9	5	25	24	100	96
	Cleveland	8	5	22	22	124	118
Okla:	Oklahoma City	10	6	24	23	78	74
Ore:	Portland	15	12	33	32	178	177
Pa:	Philadelphia	7	4	22	21	132	125
	Pittsburgh	11	6	32	31	168	159
P. R:	San Juan	7	4	13	13	77	74
R. I:	Providence	9	5	27	26	184	175
S. C:	Charleston	7	2	31	31	135	132
S. Dak:	Rapid City	23	15	45	45	166	159
Tenn:	Chattanooga	20	10	42	41	136	128
	Memphis	13	7	33	33	81	77
Tex:	Austin	4	3	9	9	45	44
	Dallas	8	4	20	20	74	70
Utah:	Salt Lake City	15	11	27	27	187	187
Vt:	Burlington	13	7	30	28	206	195
Va:	Norfolk	9	5	23	23	102	98
Wash:	Seattle	15	12	29	29	167	165
	Spokane	16	12	30	30	152	150
W. Va:	Charleston	16	8	29	28	95	89
Wis:	Milwaukee	7	4	19	19	141	136
Wyo:	Laramie	22	11	22	22	117	116
Network average		12	8	26.4	25.9	132	127

[a] Averages based on 52 weeks except for Syracuse where averages were based on 48 weeks.
[b] Iodine-131 and barium-140 averages were <10.

(5) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2,* Superintendent of Documents U. S. Government Printing Office, Washington, D. C. 20402 (September 1961). Price 20 cents.

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STRONTIUM-90 IN TRI-CITY DIETS, FEBRUARY-APRIL 1964 [1]

Health and Safety Laboratory, AEC

Since March 1960, the Health and Safety Laboratory, through its quarterly diet study, has made estimates of the strontium–90 content of the average diet of individuals living in New York City, San Francisco, and Chicago.

Selected foods representing 19 food categories are purchased at each of these three cities about every 3 months and are analyzed for strontium–90. Using data from the U.S. Department of Agriculture (*1*) the annual consumption by an average individual can be grouped into the same 19 food categories. The annual dietary intake of strontium–90 can be estimated by summing the contributions from each category. Some food types are assumed to be representative of larger food categories, such as liquid milk for dairy products in general.

The consumption data (*1*) are based on a weight-as-purchased basis. Before the food samples for the Tri-City Diet Study are ashed for radiochemical analysis, they are prepared to a certain degree as if for actual consumption. For example, fruits are peeled, eggs are shelled, and poultry is boned. Therefore, concentrations of radiocactivity in foods are reported in the Tri-City Diet Study are based on the trimmed weight. No correction is made for the waste.

After two samplings at each city it was found that the calcium content of most food categories did not vary among cities, nor did it vary significantly with time. Calcium analyses of dietary components were performed for the third time recently, and further confirmed this result (*2*). Calcium analyses were therefore discontinued and average calcium content of foods was computed and used to estimate the average annual intake of this mineral. Details of the sampling system and a discussion of the results obtained have been summarized (*3*).

Results obtained from the February-April 1964 sampling are presented in table 1. The variation with time of the daily intake of strontium–90 in the three cities is plotted in figure 1.

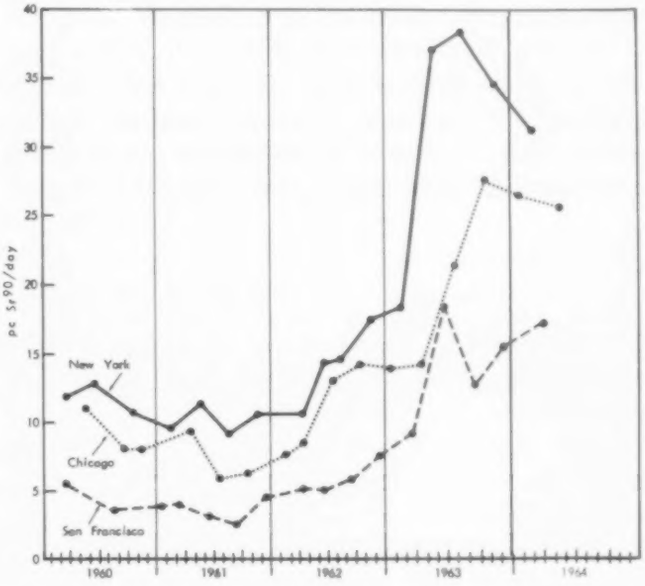

FIGURE 1.—DAILY INTAKE OF STRONTIUM–90 IN TRI-CITY DIETS

[1] Summarized from *Fallout Program Quarterly Summary Report, HASL–149:* 51–3, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (October 1, 1964) price $2.75.

TABLE 1.—AVERAGE PER PERSON DIETARY CONSUMPTION AND STRONTIUM-90 INTAKE

Food category	Average U.S. consumption		New York City February 1964		Chicago April 1964		San Francisco March 1964	
	diet (kg/yr)	Calcium (g/yr)	pc/kg [a]	pc/yr	pc/kg [a]	pc/yr	pc/kg [a]	pc/yr
Bakery products	37	37.0	26.3±1.1	973	25.9±1.3	958	25.0±1.3	925
Whole grain products	11	10.0	101±2.4	1,111	81.5±2.4	896	47.4±2.1	521
Eggs	16	9.1	8.3±0.3	133	9.8±0.2	157	5.5±0.2	88
Fresh vegetables	43	15.0	13.9±0.6	598	16.7±0.5	718	3.2±0.3	138
Root vegetables	17	6.1	9.6±0.5	163	9.8±0.5	167	8.7±0.5	148
Milk	221	234.3	25.9±0.8	5,724	18.0±0.5	3,974	15.2±0.6	3,359
Poultry	17	9.2	3.3±0.2	56	1.7±0.1	29	2.8±0.1	48
Fresh fish	8	10.8	0.9±0.2	7	4.0±0.2	32	0.7±0.1	6
Flour	43	8.6	21.3±0.4	916	23.6±0.5	1,015	10.9±0.5	469
Macaroni	3	0.7	18.4±0.5	55	24.4±0.7	73	10.5±0.4	32
Rice	3	1.1	4.8±0.2	14	5.5±0.3	16	4.8±0.2	14
Meat	73	10.9	1.9±0.1	139	1.5±0.1	110	1.4±0.8	102
Shellfish	1	0.8	3.9±0.2	4	1.1±0.1	1	3.0±0.2	3
Dried beans	3	2.9	36.0±1.8	108	29.4±1.8	88	10.2±1.6	30
Fresh fruit	68	13.6	9.8±0.4	666	5.9±0.4	401	2.6±0.3	177
Potatoes	45	5.8	8.5±0.7	382	6.9±0.7	310	3.1±0.3	140
Canned fruit	26	1.3	3.6±0.2	93	1.9±0.2	49	1.9±0.2	49
Fruit juices	19	1.7	4.1±0.3	78	4.1±0.2	78	3.4±0.2	65
Canned vegetables	20	4.2	8.6±0.6	172	10.1±0.6	202	2.7±0.3	54
Annual intake	674	383	16.8	11,392	13.8	9,274	9.4	6,368
								16.6
pc Sr^{90}/g Ca in total diet				29.7		24.2		

[a] Error terms are one standard deviation (due to counting).

Discussion

The previously noted geographic pattern of distribution of strontium–90 in the diet is seen to persist in the last sampling: levels have been highest in New York City and lowest in San Francisco. Partly due to its high annual consumption, milk continues to be the predominant source of strontium–90 in the diet.

In Chicago the strontium–90 intake was about the same as that found three months earlier. There was a slight increase in the strontium–90 intake estimated for San Francisco and a slight decrease for New York.

REFERENCES

(*1*) U. S. Department of Agriculture: *Food Consumption of Households in the United States, Report No. 1, 1955*, Household Food Consumption Survey Superintendent of Documents, Government Printing Office, Washington, D. C. 20402 (December 1956), price $1.00.

(*2*) U. S. Atomic Energy Commission: *Fallout Program Quarterly Summary Report, HASL–144:* 281–7, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (April 1, 1964), price $4.00. Summarized in *Radiological Health Data*, p. 285–8, June 1964.

(*3*) Rivera, J. and J. H. Harley: *HASL Contributions to the Study of Fallout in Food Chains, HASL–147*, Office of Technical Services, Department of Commerce, Washington, D. C. 20230 (July 1, 1964), price $1.50.

Recent coverage in *Radiological Health Data:*

Period	Issue
Thirteenth sampling (May-July 1963)	*March 1964*
Fourteenth sampling (August-October 1963)	*June 1964*
Fifteenth sampling (November 1962-January 1964)	*September 1964*

Section III—Water

GROSS RADIOACTIVITY AND STRONTIUM-90 IN SURFACE WATERS OF THE UNITED STATES, JUNE 1964

Division of Water Supply and Pollution Control, Public Health Service

Levels of radioactivity in surface waters of the United States have been monitored by the Public Health Service Water Pollution Surveillance System since its initiation in 1957. Beginning with the establishment of 50 sampling points, this system has expanded to 131 stations as of October 1, 1964. These are operated jointly with other Federal, State, and local agencies, and industry. Samples are taken from surface waters of all major U.S. river basins for physical, chemical, biological and radiological analyses. These data can be used for evaluating sources of radioactivity which may affect specific domestic, commercial, and recreational uses of surface water. Further, the system provides background information necessary for recognizing pollution and water quality trends and for determining levels of radioactivity to which the population may be exposed. Data assembled through the system and exact locations of sampling points are published in annual compilations (*1–7*).

Sampling Procedures

The participating agencies collect one-liter "grab" samples each week and ship them "as is" to the Surveillance System Laboratory in Cincinnati for analysis. Gross alpha and gross beta radioactivity determinations on the suspended and dissolved solids are performed as frequently as deemed necessary.

Presently, gross alpha and beta determinations are made on monthly composites of the weekly samples received from most stations. Weekly alpha and beta determinations are scheduled for stations located downstream from known potential sources of radioactive waste. Weekly analyses are also conducted at all newly established stations for the first year of operation.

Normally, samples are counted within two weeks following collection or within one week after compositing. The decay of activity is followed on each sample for which the first analysis shows unusually high activity. Also, if a recount indicates that the original analysis was questionable, values based on recounting are recorded. All results are reported for the time of counting and are not extrapolated to the time of collection.

Analytical Methods

The analytical method used for determining gross alpha and beta radioactivity is described in the eleventh edition of "Standard Methods for the Examination of Water and Wastewater" (*8*). Suspended and dissolved solids are separated by passing the sample through a membrane filter (type HA) with a pore size of 0.45 micron. Planchets are then prepared for counting the dissolved solids (in the filtrate) and the suspended solids (on the charred mem-

brane filter) in an internal proportional counter. Reference sources of U_3O_8, which give a known count rate if the instrument is in proper calibration, are used for daily checking of the counters.

Results

Table 1 presents June 1964 results of alpha and beta analysis of U.S. surface waters. The stations on a river are arranged in the table according to their relative location on the river, the first stations listed being closest to the headwaters. These data are preliminary. Replicate analyses of some samples as well as some analyses incomplete at the time of this report will be included in the system's "Annual Compilation of Data" (*7*). The figures for gross alpha and gross beta radioactivity represent either determinations on composite samples or means of weekly determinations where composites were not made. The monthly means are reported to the nearest pc/liter. When all samples have zero pc/liter, the mean is reported as zero; when the calculated mean is between zero and 0.5 the mean is reported as <1 pc/liter.

A geographical perspective of the radioactivity in surface water is obtained from the numbers printed near the stations as shown in figure 1 which gives the June 1964 average total beta activity in suspended-plus-dissolved solids in raw water collected at each station. Results for the years 1957-1962 have been summarized by Weaver *et al* (*9*).

Strontium–90 Determinations and Results

Beginning in 1959, strontium–90 analyses of the total solids of surface waters were made quarterly on three-month composites of aliquots from weekly samples. Beginning in November 1962, the frequency of analysis was reduced to two quarterly samples per year at each sampling point except those stations immediately below nuclear installations, where quarterly analyses were continued. The method used for determining strontium–90 is a modification of a procedure described by Harley (*10*). The yttrium–90 together with an yttrium carrier is precipitated as yttrium oxalate and the latter is washed and counted in a low-background anticoincidence, end-window proportional counter.

FIGURE 1.—SAMPLING LOCATIONS AND ASSOCIATED TOTAL BETA ACTIVITY (pc/liter) IN SURFACE WATERS, JUNE 1964

TABLE 1.—RADIOACTIVITY IN RAW SURFACE WATERS, JUNE 1964

[Average concentrations in pc/liter]

Station	Beta activity			Alpha activity		
	Suspended	Dissolved	Total	Suspended	Dissolved	Total
Allegheny River:						
Pittsbugh, Pa	0	12	12	0	0	0
Animas River:						
Cedar Hill, N. Mex	39	14	53	0	1	1
Apalachicola River:						
Chattahoochee, Fla	0	7	7	0	0	0
Arkansas River:						
Coolidge, Kansas	49	58	107	8	16	24
Ponca City, Okla	87	37	124	7	0	7
Fort Smith, Ark	39	0	39	14	3	17
Little Rock, Ark	13	24	37	2	2	4
Pendleton Ferry, Ark	13	27	40	2	2	4
Atchafalaya River:						
Morgan City, La	41	34	75	9	0	9
Bear River:						
Preston, Idaho	2	18	20	1	2	3
Big Horn River:						
Hardin, Mont	155	32	187	26	2	28
Big Sioux River:						
Sioux Falls, S. Dak	16	40	56	1	4	5
Chattahoochee River:						
Atlanta, Ga	6	3	9	1	0	1
Lanett, Ala	0	4	4	0	0	0
Columbus, Ga	20	11	31	3	0	3
Chena River:						
Fairbanks, Alaska	0	10	10	0	0	0
Clearwater River:						
Lewiston, Idaho	12	8	20	2	0	2
Clinch River:						
Clinton, Tenn	1	9	10	0	<1	<1
Kingston, Tenn	14	79	93	0	<1	<1
Colorado River:						
Loma, Colo	60	20	80	13	2	15
Page, Ariz	4	41	45	0	9	9
Boulder City, Nev	1	14	15	0	2	2
Parker Dam, Calif-Ariz	1	25	26	0	20	20
Yuma, Ariz	4	22	26	1	12	13
Columbia River:						
Northport, Wash	1	12	13	0	0	0
Wenatchee, Wash	2	9	11	0	0	0
Pasco, Wash	119	214	333	0	<1	<1
McNary Dam, Ore	20	44	64	<1	<1	<1
Bonneville, Ore	54	78	132	0	1	1
Clatskanie, Ore	27	54	81	<1	0	<1
Connecticut River:						
Wilder, Vt	4	7	11	1	0	1
Northfield, Mass	8	7	15	1	0	1
Enfield Dam, Conn	0	8	8	1	0	1
Cuyahoga River:						
Cleveland, Ohio	7	34	41	0	1	1
Delaware River:						
Martins Creek, Pa	2	9	11	0	0	0
Trenton, N. J	9	13	22	0	1	1
Philadelphia, Pa	0	12	12	0	0	0
Escambia River:						
Century, Fla	4	7	11	0	0	0
Great Lakes:						
Duluth, Minn	0	0	0	0	0	0
Sault Ste. Marie, Mich	0	10	10	0	0	0
Milwaukee, Wis	0	4	4	0	0	0
Gary, Ind	0	4	4	0	0	0
Port Huron, Mich	1	10	11	0	0	0
Detroit, Mich	3	11	14	1	1	2
Buffalo, N. Y	5	16	21	0	0	0
Green River:						
Dutch John, Utah	0	27	27	0	0	0
Hudson River:						
Poughkeepsie, N. Y	2	9	11	0	0	0
Illinois River:						
Peoria, Ill	10	29	39	2	4	6
Grafton, Ill	3	15	18	1	3	4
Kanawha River: Winfield Dam, W. Va	2	13	15	0	1	1
Kansas River:						
De Soto, Kans	202	38	240	17	2	19
Klamath River:						
Keno, Ore	2	25	27	0	1	1
Little Miami River:						
Cincinnati, Ohio	11	16	27	1	1	2
Maumee River:						
Toledo, Ohio	6	31	37	0	2	2
Merrimack River:						
Lowell, Mass	5	13	18	0	0	0
Mississippi River:						
St. Paul, Minn	6	40	46	0	0	0
Dubuque, Iowa	0	31	31	0	0	0
Burlington, Iowa	10	25	35	0	0	0
E. St. Louis, Ill	89	0	89	28	1	29
Cape Girardeau, Mo	66	32	98	5	3	8
W. Memphis, Ark	25	23	48	8	1	9
Vicksburg, Miss	32	23	55	8	2	10
Delta, La	47	28	75	10	1	11
New Roads, La	32	26	58	6	1	7
New Orleans, La	9	12	21	2	1	3
Missouri River:						
Williston, N. Dak	9	27	36	0	1	1
Bismarck, N. Dak	12	31	43	1	5	6
Yankton, S. Dak	2	43	45	0	4	4
Omaha, Nebr	26	29	55	8	5	13
St. Joseph, Mo	173	183	356	26	3	29
Kansas City, Kans	132	25	157	30	4	34
Missouri City, Mo	669	57	726	271	4	275
St. Louis, Mo	112	24	136	25	2	27
Monongahela River:						
Pittsburgh, Pa	3	25	28	0	0	0
North Platte River:						
Henry, Nebr	26	49	75	2	19	21
Ohio River:						
Toronto, Ohio	0	19	19	0	0	0
Addison, Ohio	0	12	12	0	0	0
Huntington, W. Va	3	12	15	0	0	0
Cincinnati, Ohio	5	8	13	1	0	1
Louisville, Ky	0	9	9	0	0	0
Evansville, Ind	0	16	16	0	1	1
Cairo, Ill	7	19	26	1	0	1
Ouachita River:						
Bastrop, La	6	18	24	0	1	1
Pend Oreille River:						
Albeni Falls Dam, Idaho	8	8	16	1	1	2
Platte River:						
Plattsmouth, Nebr	261	35	296	30	2	32
Potomac River:						
Williamsport, Md	1	12	13	0	0	0
Great Falls, Md	2	12	14	0	0	0
Washington, D.C	4	10	14	<1	<1	<1
Rainy River:						
Baudette, Minn	10	39	49	0	1	1
International Falls, Minn	4	25	29	0	0	0
Raritan River:						
Perth Amboy, N. J. (5 ft. Below Surface)	0	7	7	0	3	3
Perth Amboy, N. J. (5 ft. Above Bottom)	0	12	12	0	4	4
Red River, North:						
Grand Forks, N. Dak	19	58	77	0	5	5
Red River, South:						
Denison, Tex	3	25	28	0	4	4
Index, Ark	1	43	44	0	3	3
Bossier City, La	3	25	28	0	2	2
Alexandria, La	13	5	18	0	1	1
Rio Grande River:						
Alamosa, Colo	9	20	29	1	1	2
El Paso, Tex	15	20	35	3	3	6
Laredo, Tex	985	35	1,020	156	2	158
Brownsville, Tex	2	15	17	0	1	1
Roanoke River:						
John H. Kerr Resr/ Dam, Va	5	13	18	0	0	0
Sabine River:						
Ruliff, Tex	13	19	32	1	0	1
Sacramento River:						
Courtland Calif	0	5	5	0	0	0
St. Lawrence River:						
Massena, N. Y	4	7	11	0	0	0
San Joaquin River:						
Vernalis, Calif	10	39	49	2	19	21
San Juan River:						
Shiprock, N. Mex	25	21	46	4	6	10
Savannah River:						
North Augusta, S. C.	5	15	20	0	0	0
Port Wentworth, Ga.	15	16	31	1	0	1
Schuylkill River:						
Philadelphia, Pa	1	12	13	0	1	1
Shenandoah River:						
Berryville, Va	0	11	11	0	0	0
Ship Creek:						
Anchorage, Alaska	6	5	11	0	0	0
Snake River:						
Ice Harbor Dam, Wash	4	7	11	0	0	0
Wawawai, Wash	10	10	20	1	0	1
South Platte River:						
Julesburg, Colo	1	66	67	0	36	36
Spokane River:						
Post Falls Dam, Idaho	4	3	7	0	0	0
Susquehanna River:						
Sayre, Pa	6	4	10	0	1	1
Conowingo, Md	2	8	10	0	0	0
Tennessee River:						
Lenoir City, Tenn	5	9	14	0	0	0
Chattanooga, Tenn	2	18	20	<1	0	<1
Bridgeport, Ala	5	16	21	0	0	0
Pickwick Landing, Tenn	3	11	14	0	0	0
Tombigbee River:						
Columbus, Miss	5	11	16	0	0	0
Truckee River:						
Farad, Calif	0	5	5	1	0	1
Verdigris River:						
Nowata, Okla	41	24	65	3	1	4
Wabash River:						
New Harmony, Ind	21	17	38	3	0	3
Willamette River:						
Portland, Ore	3	2	5	0	0	0
Yakima River:						
Richland, Wash	1	5	6	0	0	0
Yellowstone River:						
Sidney, Mont	248	33	281	72	3	75
Maximum	985	214	1,020	271	36	275
Minimum	0	0	0	0	0	0

Note: These data are preliminary; reanalysis of some samples may be made and additional analysis not completed at the time of the report may become available. For final data, one should consult the system's annual report.

TABLE 2.—QUARTERLY AVERAGE STRONTIUM-90 CONCENTRATIONS IN SURFACE WATERS, JULY 1963–JUNE 1964

[Concentrations in pc/liter]

Station	July–Sept. 1963	Oct.–Dec. 1963	Jan.–Mar. 1964	Apr.–June 1964
Allegheny River:				
Pittsburgh, Pa	[a]—	2.8	—	2.3
Animas River:				
Cedar Hill, N. Mex	1.8	—	1.7	—
Apalachicola River:				
Chattahoochee, Fla	2.9	—	1.5	—
Arkansas River:				
Coolidge, Kans	6.6	—	0.9	—
Ponca City, Okla	6.5	4.4	—	6.0
Fort Smith, Ark	6.7	—	3.5	—
Little Rock, Ark	4.8	4.4	—	4.2
Pendleton Ferry, Ark	—	4.3	—	4.4
Bear River:				
Preston, Idaho	3.7	—	1.1	—
Big Horn River:				
Hardin, Mont	—	2.3	—	6.4
Big Sioux River:				
Sioux Falls, S. Dak	9.5	5.0	2.8	—
Chattahoochee River:				
Atlanta, Ga	—	1.7	—	2.4
Columbus, Ga	—	1.7	—	2.0
Lanett, Ala	2.0	—	1.7	—
Chena Slough:				
Fairbanks, Alaska	—	0.2	—	0.8
Clearwater River:				
Lewiston, Idaho	1.2	—	0.8	—
Clinch River:				
Clinton, Tenn	1.4	—	2.0	—
Kingston, Tenn	9.4	6.5	7.5	4.9
Colorado River:				
Loma, Colo	—	1.4	—	2.5
Page, Ariz	4.2	—	5.9	—
Boulder City, Nev	—	1.5	—	1.6
Parker Dam, Calif-Ariz	1.0	—	1.9	—
Yuma, Ariz	—	1.1	—	1.0
Columbia River:				
Northport, Wash	3.4	—	1.5	—
Wenatchee, Wash	—	2.8	—	1.2
Pasco, Wash	2.7	3.4	3.1	1.7
McNary Dam, Ore	2.6	2.5	2.2	1.1
Bonneville, Ore	1.2	—	2.0	—
Clatskanie, Ore	2.5	1.6	—	1.0
Connecticut River:				
Wilder, Vt	2.6	—	1.3	—
Northfield, Mass	3.1	1.8	—	1.5
Enfield Dam, Conn	2.5	—	1.7	—
Cumberland River:				
Clarksville, Tenn	2.0	—	—	—
Cuyahoga River:				
Cleveland, Ohio	5.3	—	4.3	—
Delaware River:				
Martins Creek, Pa	—	1.6	—	1.5
Trenton, N. J	3.1	—	1.8	—
Philadelphia, Pa	—	2.1	—	2.0
Escambia River:				
Century, Fla	—	1.2	—	1.8
Great Lakes:				
Duluth, Minn	—	0.7	—	0.7
Sault Ste. Marie, Mich	1.5	—	0.8	—
Milwaukee, Wis	—	0.8	—	1.2
Gary, Ind	1.6	—	1.2	—
Port Huron, Mich	—	1.2	—	1.5
Detroit, Mich	2.4	—	1.4	—
Buffalo, N. Y	—	2.5	—	2.7
Green River:				
Dutch John, Utah	2.7	—	4.6	—
Hudson River:				
Poughkeepsie, N. Y	—	5.0	—	2.1
Illinois River:				
Peoria, Ill	—	2.3	—	3.8
Grafton, Ill	4.4	—	3.8	—
Kanawha River:				
Winfield Dam, W. Va	2.9	—	1.1	—
Kansas River:				
De Soto, Kans	7.4	5.2	—	5.9
Klamath River:				
Keno, Ore	—	1.8	—	1.7
Little Miami River:				
Cincinnati, Ohio	5.3	1.4	3.3	—
Maumee River:				
Toledo, Ohio	—	2.7	—	4.2
Merrimack River:				
Lowell, Mass	1.6	—	1.8	—
Mississippi River:				
St. Paul, Minn	7.2	4.3	3.2	—
Dubuque, Iowa	—	3.7	—	5.2
Burlington, Iowa	7.3	4.3	2.8	—
E. St. Louis, Ill	—	3.8	—	4.9
Cape Girardeau, Mo	5.3	—	2.9	—
W. Memphis, Ark	—	3.6	—	4.3
Vicksburg, Miss	4.2	—	2.7	—
Delta, La	—	3.4	3.6	—
New Roads, La	—	—	—	3.6
New Orleans, La	4.5	—	2.8	—
Missouri River:				
Williston, N. Dak	—	2.8	—	3.1
Bismarck, N. Dak	3.5	—	3.9	—
Yankton, S. Dak	—	3.3	—	4.3
Omaha, Nebr	4.5	—	3.3	—
St. Joseph, Mo	—	3.4	—	6.4
Kansas City, Kans	5.0	—	2.9	—
Missouri City, Mo	—	4.1	—	9.4
St. Louis, Mo	6.2	—	3.1	—
Monongahela River:				
Pittsburgh, Pa	3.3	3.3	—	2.1
North Platte River:				
Henry, Nebr	—	0.7	—	3.3
Ohio River:				
Toronto, Ohio	4.9	2.8	—	2.3
Addison, Ohio	4.0	—	2.2	—
Huntington, W. Va	—	3.0	—	2.2
Cincinnati, Ohio	3.7	—	1.6	—
Louisville, Ky	3.6	4.0	—	2.6
Evansville, Ind	4.2	—	2.5	—
Cairo, Ill	—	2.8	—	3.4
Ouachita River:				
Bastrop, La	4.5	—	3.0	—
Pend Oreille River:				
Albeni Falls Dam, Idaho	—	1.3	—	1.2
Platte River:				
Plattsmouth, Nebr	5.2	—	2.1	—
Potomac River:				
Williamsport, Md	—	1.7	—	1.3
Great Falls, Md	2.5	—	1.4	—
Washington, D. C	3.4	—	1.2	—
Rainy River:				
Baudette, Minn	4.7	4.1	—	4.0
International Falls, Minn	4.3	3.8	—	5.0
Red River, North:				
Grand Forks, N. Dak	11.3	7.1	4.9	9.4
Red River, South:				
Denison, Tex	5.6	—	5.8	—
Index, Ark	4.9	4.3	—	5.4
Bossier City, La	5.0	—	4.4	—
Alexandria, La	—	4.1	—	4.4
Rio Grande River:				
Alamosa, Colo	—	0.8	—	1.9
El Paso, Tex	1.9	—	0.6	—
Laredo, Tex	—	2.4	—	5.6
Brownsville, Tex	2.3	—	2.6	—
Roanoke River:				
John H. Kerr Resr/Dam, Va	—	2.6	—	1.5
Sabine River:				
Ruliff, Tex	3.2	—	2.5	—
Sacramento River:				
Courtland, Calif	1.4	1.0	1.0	—
St. Lawrence River:				
Massena, N. Y	2.3	—	1.6	—
San Joaquin River:				
Vernalis, Calif	—	1.5	—	1.0
San Juan River:				
Shiprock, N. Mex	—	2.1	—	2.9
Savannah River:				
North Augusta, So. Car	2.1	—	1.7	—
Port Wentworth, Ga	3.2	2.4	1.7	2.3
Schuylkill River:				
Philadelphia, Pa	3.7	—	1.4	—
Shenandoah River:				
Berryville, Va	—	1.0	—	1.1
Ship Creek:				
Anchorage, Alaska	0.9	—	0.4	—
Snake River:				
Ice Harbor Dam, Wash	1.3	—	1.0	—
Wawawai, Wash	—	0.7	—	1.0
Payette, Idaho	—	0.8	—	0.9
South Platte River:				
Julesburg, Colo	—	1.8	—	1.6
Spokane River:				
Post Falls, Idaho	1.2	—	1.3	—
Susquehanna River:				
Sayre, Pa	2.3	—	1.3	—
Conowingo, Md	—	3.0	—	1.3
Tennessee River:				
Lenoir City, Tenn	—	2.1	—	1.6
Chattanooga, Tenn	3.3	2.2	2.0	2.3
Bridgeport, Ala	—	2.2	—	1.5
Pickwick Landing, Tenn	2.5	—	2.1	—
Tombigbee River:				
Columbus, Miss	3.6	—	3.1	—
Truckee River:				
Farad, Calif	—	1.0	—	1.2
Verdigris River:				
Nowata, Okla	—	6.0	—	6.6
Wabash River:				
New Harmony, Ind	—	2.5	—	4.2
Willamette River:				
Portland, Ore	—	0.5	—	0.3
Yakima River:				
Richland, Wash	1.0	—	0.3	—
Yellowstone River:				
Sindey, Mont	5.0	—	1.9	—
Maximum	11.3	7.1	7.5	9.4
Minimum	0.9	0.2	0.8	0.3

[a] No sample reported.

Table 2 presents the results of quarterly analyses of strontium–90 concentrations in U.S. surface waters for April-June 1964 as well as results for the previous three quarters for comparative purposes. The stations are arranged in the table according to their relative locations on the river, the first station being closest to the headwaters. Floyd and Weaver summarized the strontium–90 results obtained from 1959 through 1963 in the August 1964 issue of *RHD* (*11*).

Sixty-nine quarterly composite samples were analyzed for strontium–90 activity in April-June 1964. The arithmetic mean for these 69 results was 3.0 pc/liter and the median was 2.3 pc/liter. The mean for 64 results of the previous quarter (January, February, March 1964) was 2.5 and the median was 2.0 pc/liter. This increase can be attributed largely to seasonal "runoff".

Two stations had strontium–90 levels equal to or greater than 7.5 pc/liter, which was the highest reported level during the previous quarter. These were Grand Forks (Red River North) and Missouri City (Missouri River), both with 9.4 pc/liter. While there are no standards for strontium–90 activity of total solids in surface water, the Public Health Service Drinking Water Standards set the limit for strontium–90 concentrations in drinking water at 10 pc/liter (*12*). This limit for public water supplies is greater than the highest level observed during April-June 1964.

Discussion

The monthly dissolved beta activity averages exceeded 100 pc/liter at two stations. These values were 214 pc/liter on the Columbia River and 183 pc/liter on the Missouri River. The gross beta activity (quarterly median of monthly means) for this period for the original radioactivity-baseline stations was 43 pc/liter, compared to 27 pc/liter for the previous quarter.

The dissolved alpha activity, which is associated with the dissolving of natural surface minerals by water, ranged from zero to 36 pc/liter. Of all stations, six stations on five rivers had monthly average dissolved alpha activity greater than 10 pc/liter.

The radioactivity associated with dissolved solids provides a rough indication of the levels which could occur in treated water, since nearly all suspended matter is removed by the treatment process (*13*). The Public Health Service Drinking Water Standards state that in the absence of strontium–90 and alpha emitters,[1] a water supply is acceptable when the gross beta concentration does not exceed 1000 pc/liter (*12*).

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[1] Absence is taken here to mean a negligibly small fraction of the specific limits of 3 pc/liter and 10 pc/liter for unidentified alpha emitters and strontium–90, respectively.

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(*9*) Weaver, L., A. W. Hoadley, and S. Baker: Radioactivity in Surface Waters of the United States, 1957-1962, *Radiological Health Data, 4:* 306–16, (June 1963).
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(*13*) Straub, C. P.: Significance of Radioactivity Data, *Journal of the American Water Works Association, 53:* 704 (June 1961).

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[2] Single free copies of this publication may be obtained from: Public Inquiries Branch, Public Health Service, U. S. Department of Health, Education, and Welfare, Washington, D. C. 20201.

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RADIOACTIVITY IN NEW YORK SURFACE WATER JULY 1963—JUNE 1964

Division of Environmental Health Services
State of New York Department of Health

The New York Department of Health began a program in January 1955 to determine the amount of radioactivity in water used for public consumption. This radioactivity in water may arise from the natural mineral content of water (background), from atmospheric fallout, and from nuclear industry operations. Water samples are obtained monthly from twenty-six cities for gross beta analysis. Samples are obtained more frequently from four cities for strontium–90 analyses.

Samples are sent to the Division of Laboratories and Research for analysis. Table 1 shows the gross beta concentrations and table 2 shows the radiostrontium concentrations in water from January 1963–June 1964. Albany and Cohoes water receives standard chlorination, coagulation and gravity rapid sand filtration and New York City receives chlorination. It is of note that the Cohoes gross beta results are for the raw water source while the Cohoes strontium–89 and strontium–90 results are for the finished water.

TABLE 1.—GROSS BETA ACTIVITY IN NEW YORK RAW SURFACE WATER, NOVEMBER 1963-JUNE 1964

[Concentration in pc/liter]

Location	1963		1964					
	November	December	January	February	March	April	May	June
Akron (Murder Creek) [a]	13	21	16	13	15	11	11	13
Bedford (Byram Lake) [b]	18	8	9	3	23	15	15	10
Cape Vincent (St. Lawrence R.) [b]	—	—	—	—	Began in April	6	—	—
Clarkstown (Congers Lake) [b]	33	—	22	15	25	56	26	28
Clarkstown (Lake De Forest) [b]	<3	—	18	20	13	21	12	10
Cohoes (Mohawk River) [c]	13	26	9	9	11	—	—	7.0
Glenmont (Hudson River) [d]	13	17	9	9	11	12	8	7.5
Haverstraw (Letchworth V. Res.) [b]	10	—	8	5	7	7	5	5
Highland Falls (Bog Meadow Brook) [b]	4	5	6	<3	11	5	12	5
Niagara Falls (W. Branch Niagara River) [b]	5	—	7	—	8	11	—	7
Niagara Falls (E. Branch Niagara River) [b]	7	—	6	—	11	16	—	9
Ossining (Hudson R.) (Sing Sing) [a]	53	30	58	56	20	13	27	36
Ossining (Indian Bank Res.) [b]	28	—	13	16	15	20	13	7
Oswego (Lake Ontario) [c]	7	6	6	10	7	7	6	6
Pawling (Pond at United Nuclear) [b]	25	18	7	16	20	<	12	8
Peekskill (Hudson River) [c]	21	23	24	12	12	19	9	22
Peekskill (Camp Fields WS) [e]	21	11	9	13	10	19	8	10
Ramapo (Hillburn WS) [b]	17	—	9	5	3	12	6	3
Rome (Fish Creek) [a]	15	16	10	8	13	14	8	8
Schenectady (Mohawk River) [c]	10	13	8	5	11	11	8	7
Stony Point (Iowa Island W.S.) [b]	<3	—	5	<3	8	6	1	5
Tuxedo (Indian Kill Outfall) [c]	18	15	7	<3	7	13	7	9
Waterford (Hudson River) [a]	9	10	13	13	23	14	7	5
Watertown (Black River) [b]	15	17	23	12	14	16	9	8
Watervliet (French Mills Res.) [b]	8	9	18	11	12	6	7	5
Yorktown (Croton Res.) [c]	14	9	<3	3	14	21	19	10

[a] Bi-weekly composite of daily grab samples.
[b] Monthly grab sample.
[c] Continuous bleed-off analyzed weekly.
[d] Weekly composite of daily grab samples.
[e] Weekly grab sample.

TABLE 2.—STRONTIUM-89 AND STRONTIUM-90 LEVELS IN NEW YORK WATER

[Average concentrations in pc/liter]

Location	1963						1964				
	July	August	September	October	November	December	January	February	March	April	May
Albany [a]											
Strontium-89	<3	5	5	7	5	<3	<3	<3	<3	<3	<3
Strontium-90	3	<3	<3	<3	<3	<3	3	<3	4	3	3
Cohoes [b]											
Strontium-89	6	10	12	15	4	<3	<3	<3	<3	<3	<3
Strontium-90	7	7	6	9	9	6	5	<3	<3	<3	4.5
Geneva [c]											
Strontium-89	<3	<3	<3	3	<3	<3	<3	<3	<3	<3	<3
Strontium-90	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
New York City											
Strontium-89	4	8	7	9	<3	<3	<3	<3	<3	<3	<3
Strontium-90	4	<3	<3	<3	<3	<3	<3	<3	3	<3	<3

[a] Weekly composite of daily grab samples.
[b] Continuous bleed-off analyzed weekly.
[c] Bi-weekly composite of daily grab samples.

For gross beta analysis, a measured quantity of water is evaporated and the residue is analyzed in an end-window gas flow proportional counter.

For strontium–89, strontium–90 and yttrium–90 analysis, a measured quantity of water is passed through an ion exchange resin column and the strontium is retained on the resin. The strontium is then eluted from the resin, concentrated and beta counted as strontium sulfate using a low background end-window gas flow proportional counter. Successive beta counting of the sample at two-day intervals enables the determination of strontium–90, strontium–89 and yttrium–90 to be made.

Section IV—Other Data

ENVIRONMENTAL LEVELS OF RADIOACTIVITY AT ATOMIC ENERGY COMMISSION INSTALLATIONS

The U.S. Atomic Energy Commission receives from its contractors semi-annual reports on the environmental levels of radioactivity in the vicinity of major Commission installations. The reports include data from routine monitoring programs where operations are of such a nature that plant perimeter surveys are required.

Summaries of the environmental radioactivity data for 22 AEC installations have appeared periodically in *RHD* since November 1960. Summaries follow for Brookhaven National Laboratory and Rocky Flats Plant.

Releases of radioactive materials from these installations for the periods covered in the reports below are regulated in accordance with AEC standards as set forth in the Federal Register Title 10—Part 20 (*1*). The appropriate concentration standards are given in table 1.

1. Brookhaven National Laboratory
July 1963-June 1964

Associated Universities, Inc.
Upton, New York

The Brookhaven National Laboratory (BNL) operations may affect the environmental levels of radiation in three ways: (1) by discharge of coolant air from the graphite research reactor, (2) by radiation from an ecology forest gamma source, and (3) by the discharge of low level radioactive liquid wastes into a small stream that forms one of the headwaters of the Peconic River (figure 1).

TABLE 1.—SELECTED ENVIRONMENTAL MPC VALUES PERTAINING TO AEC INSTALLATION REPORTS IN THIS SUBSECTION

Line No.	Radionuclide or mixture of unknown nuclides	Environmental MPC's	
		Water (pc/liter)	Air (pc/m³)
1	If Sr^{90}, I^{129}, Pb^{210}, Po^{210}, At^{211}, Ra^{223}, Ra^{224}, Ra^{226}, Ac^{227}, Ra^{228}, Th^{230}, Pa^{231}, Th^{232}, and Th-nat are not present [a]	3,000	—
2	If Sr^{90}, Pb^{210}, Ra ^{226}, Ra^{228} are not present [a]	600	—
3	If Ra^{226}, Ra^{228} are not present [a]	100	—
4	Mixture of unidentified nuclides	10	0.04
5	If α emitters and Ac^{227} are not present [a]	—	1.0
6	If α emitters and Pb^{210}, Ac^{227}, Ra^{228}, Pu^{241} are not present [a]	—	10
7	If α emitters and Sr^{90}, I^{129}, Pb^{210}, Ac^{227}, Ra^{228}, Pa^{230}, Pu^{241}, Bk^{249} are not present [a]	—	100
8	Argon-41 (immersion)	—	40,000
9	Plutonium-239	5,000	0.06
10	Uranium-natural	20,000	2

[a] The concentration standards given here were taken from The Atomic Energy Commission's regulation 10 CFR Part 20, Federal Register, (*1*).
[b] "Not present" implies that the concentration of the nuclide is small compared with its appropriate MPC. According to Federal Register, Title 10, Part 20, (*1*), a group of nuclides may be considered not present if the ratio of each nuclide to its appropriate MPC is equal to or less than 1/10 and if the sum of these ratios for the group in question is equal to or less than ¼.

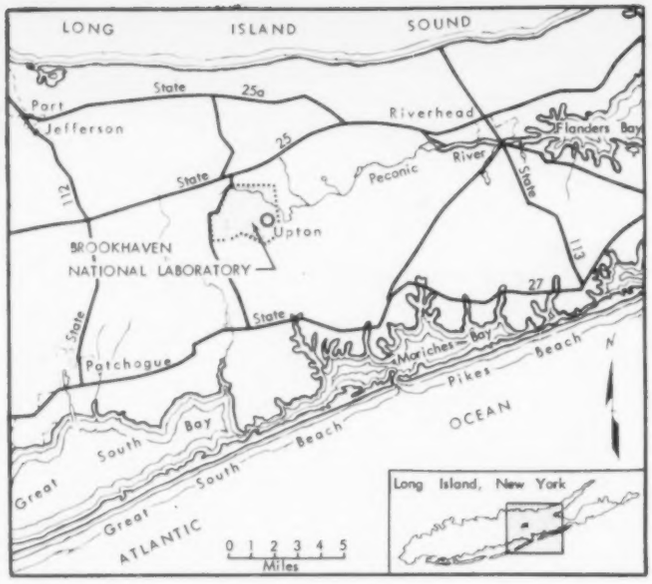

FIGURE 1.—BROOKHAVEN NATIONAL LABORATORY AND SURROUNDING AREA

TABLE 2.—EXTERNAL GAMMA LEVELS AT BNL SITE BOUNDARY

(Average exposure rates in mr/wk)

Period	North gate [1]	Southwest perimeter	Southeast perimeter	Northeast perimeter
Gamma exposure from laboratory operations				
1963				
July	0.47	0.25	0.42	3.56
August	0.17	0.01	0.48	3.13
September	0.21	0.70	0.27	2.45
October	0.41	0.57	0.53	2.50
November	0.31	0.39	0.45	2.17
December	0.19	0.25	0.39	1.63
1964				
January	0.15	0.13	0.43	1.45
February	0.11	0.08	0.92	1.42
March	0.20	0.51	0.65	2.55
April	0.54	0.39	0.44	2.36
May	0.25	0.98	0.23	2.83
June	0.27	0.43	0.52	3.36
Second half 1963	0.29	0.35	0.42	2.61
First half 1964	0.25	0.43	0.52	2.33
Undisturbed background				
Second half 1963	5.94	5.41	5.92	5.89
First half 1964	2.78	2.90	3.13	3.28

[1] North gate station is located 680 meters inside boundary. The others are on the boundary.

Area Monitoring

The radioactivity in the discharge coolant air is almost entirely that of argon–41, a beta-gamma emitter. Because exposure to argon–41 is due to external gamma, the monitoring is performed by measuring the exposure-rate in milliroentgens per week (mr/wk) rather than the concentration in air.

Late in 1961 a 10,000 curie cesium–137 gamma source was installed in the ecology forest about 800 meters equidistant from the north and east boundaries (*2*).

Table 2 presents the average external gamma exposure rates measured at the four stations shown in figure 2. The higher levels at the Northeast perimeter station are primarily due to the ecology forest source. The environmental maximum permissible dose recommended by the FRC is 0.5 rem/yr (10 mrem/wk) above natural background, averaged over a one-year period.

Water Monitoring

The BNL liquid waste effluent is monitored for gross beta concentrations at the site boundary. Table 3 presents the average concentration together with the total activity released as determined by using known effluent flow rates.

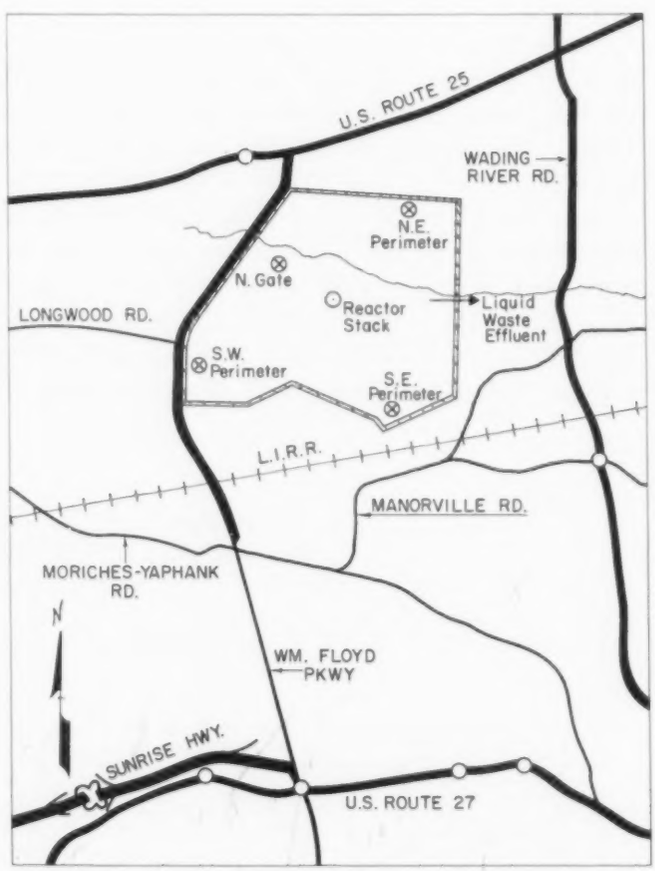

FIGURE 2.—BROOKHAVEN NATIONAL LABORATORY MONITORING STATION LOCATIONS

TABLE 3.—GROSS BETA ACTIVITY IN BNL LIQUID WASTE EFFLUENT

Period	Average beta concentration (pc/liter)	Total beta activity discharged (mc)
1963		
July	103	9.3
August	71	7.0
September	115	10.9
October	86	6.9
November	95	7.1
December	80	5.7
1964		
January	53	5.1
February	79	6.0
March	83	6.3
April	43	4.8
May	77	9.1
June	128	11.1
Second Half 1963	92	46.9
First Half 1964	75	42.4

Previous coverage in *Radiological Health Data:*

Period	Issue
1959 and first quarter 1960	*December 1960*
Second quarter 1960	*February 1961*
Third and fourth quarters 1960	*June 1961*
First and second quarters 1961	*January 1962*
Third and fourth quarters 1961	*June 1962*
First and second quarters 1962	*January 1963*
July 1962 to June 1963	*February 1964*

2. Rocky Flats Plant
July 1963-June 1964

Dow Chemical Company, Denver, Colorado

The Rocky Flats Plant (RFP) is engaged in routine production operations involving plutonium under contract to the Atomic Energy Commission. Its location relative to population centers is shown in figure 3. To assure properly controlled release of radioactive materials to the environment, periodic samples of water, air, and vegetation are analyzed for gross alpha activity. The most abundant radioactive material involved in the process is plutonium.

The plant is located on gravel washed out of the highly mineralized Front Range of the Rocky Mountains, where heterogeneous low-level deposits of uranium, thorium, and radium exist in the soil. These materials are measurable in most samples of air, water, and vegetation.

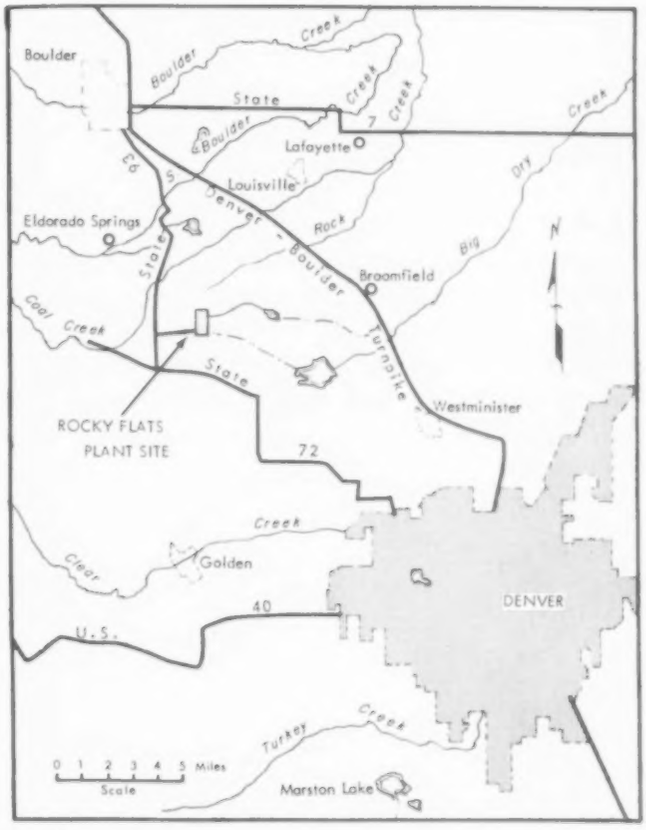

FIGURE 3.—LOCATION OF THE ROCKY FLATS PLANT ENVIRONMENT, DENVER, COLORADO

Air

Continuous 24-hour air samples were collected at Coal Creek Canyon, Marshall, Boulder, Lafayette, Broomfield, Wagner School, Golden, Denver, and Westminster. The monthly average long-lived gross alpha activities are shown in table 4. The alpha activity is believed to consist entirely of naturally occurring materials.

TABLE 4.—LONG-LIVED ALPHA ACTIVITY IN PARTICULATES IN AIR, RFP

Month	Average alpha concentration (pc/m^3)
1963	
July	<0.002
August	<0.001
September	<0.005
October	<0.003
November	<0.005
December	<0.007
1964	
January	<0.007
February	<0.005
March	<0.009
April	<0.007
May	0.013
June	<0.003

Water Monitoring

Semi-monthly water samples were collected from four reservoirs at distances ranging from 3 to 8 miles from RFP. The average alpha concentrations in the four reservoirs during the second half of 1963 and first half of 1964 are shown in table 5.

Non-routine raw surface water samples were collected from a number of outlying streams and lakes during fall and spring vegetation collections. The 35 samples collected during the second half of 1963 had an average gross alpha activity of 2.1 pc/liter. The semi-annual sampling was postponed for the first half of 1964.

TABLE 5.—ALPHA ACTIVITY IN RESERVOIRS IN THE VICINITY OF ROCKY FLATS PLANT

[Average concentrations in pc/liter]

Reservoir	Second half 1963	First half 1964
Great Western	2.2	3.2
Standley	2.5	2.7
Baseline	1.7	1.4
Ralston	1.4	3.9

Vegetation Samples

A total of 281 vegetation samples were analyzed during the 12-month period covered by this report. The average gross alpha activities of these samples are shown in table 6.

TABLE 6.—GROSS ALPHA ACTIVITY IN VEGETATION

Samples collected	Analysis made	Distance from plant	Number of samples	Average concentration (pc/kg dry)
1963	1963	<3 miles	30	111
	1963	3–18 miles	12	99
1962–1963	1964	<3 miles	100	154
		3–18 miles	24	134
1963	1964	<3 miles	72	200
		3–18 miles	43	210

Previous coverage in *Radiological Health Data:*

Period	Issue
Second half 1960 and First half of 1961	*November 1961*
Second half 1961	*May 1962*
First half 1962	*January 1963*
July 1962 and June 1963	*February 1964*

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(2) Hull, A. P.: 1962 Environmental Radiation Levels at Brookhaven National Laboratory, BNL 807 (T–310) (Health and Safety—TID—4500, 21st Ed) May 1963, Office of Technical Services, Department of Commerce, Washington D. C., 20430.

RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER, 1962–1964

Division of Radiological Health, Public Health Service

A new phase in assessing the radionuclide intake of Alaskan residents began in 1963, when caribou and reindeer sampling and analysis were undertaken by the Alaskan Departments of Health and Welfare and of Fish and Game and the Public Health Service under a cooperative agreement between these agencies. The basis for this joint activity stemmed from a more limited sampling effort conducted by these groups in 1962.

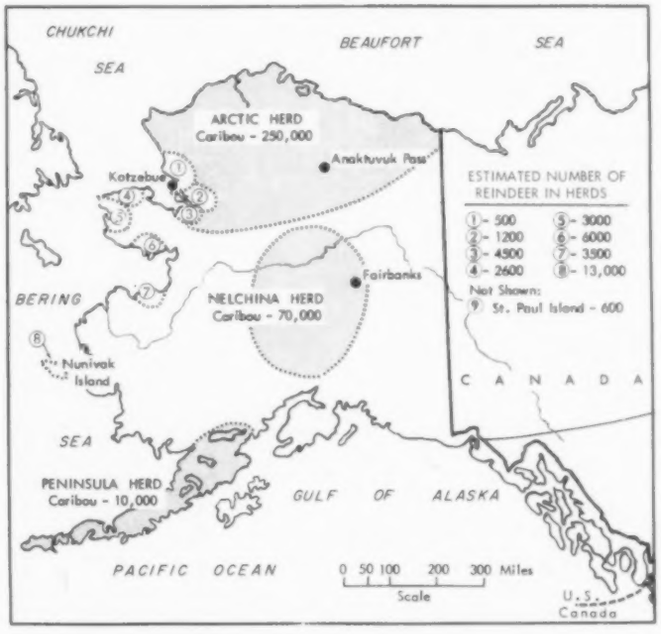

FIGURE 1.—NUMBERS OF RUMINANTS IN HERDS SAMPLED, 1964

Through the second quarter of 1964, the sampling was confined to the three principal caribou (*Rangifer caribou*) herds and one privately owned reindeer (*Rangifer tarandus*) herd. This program was expanded when, beginning in September 1964, the sampling of additional privately-owned reindeer herds was begun through the assistance of the Fish and Wildlife Service and Bureau of Indian Affairs, Department of Interior.

Figure 1 shows the locations and approximate number of animals in the caribou and reindeer herds sampled. In general, the reindeer herds are located on or near the Seward peninsula and on two islands off the western coast of Alaska.

Samples of muscle rumen contents and bone from 5 animals (two- or three-years old) in each herd sampled are collected in approximately April, July, September and December of each year. The muscle samples, weighing about two pounds each, are frozen for shipment. The bone samples consist of the hock from each animal. The rumen content samples, weighing about two pounds wet, are dried for shipment. All samples are shipped in dry ice to the Public Health Service Southwestern Radiological Health Laboratory in Las Vegas, Nevada, for analysis.

The analytical procedure includes gamma scintillation spectroscopy for potassium–40, zirconium-niobium–95, ruthenium–106, and cesium–137. Strontium–89 and strontium–90 are determined by chemical separation followed by beta counting. Analysis for stable calcium is done by a flame photometric method.

Zirconium-niobium–95, ruthenium–106 and cesium–137 results are presented in tables 1-3 for caribou and reindeer muscle, rumen contents and bone, respectively. Data for cesium–137 in caribou muscle and rumen contents are shown in figures 2 and 3.

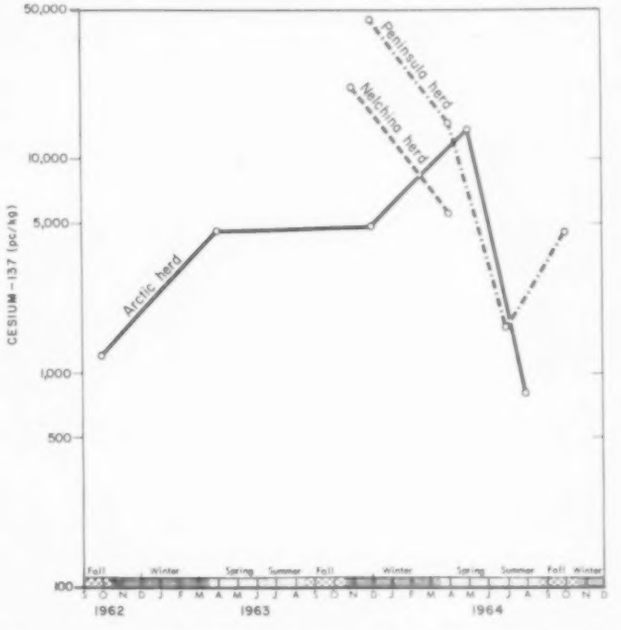

FIGURE 2.—CESIUM–137 IN CARIBOU MUSCLE

TABLE 1.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER MUSCLE

Specimens & sampling dates	(pc/kg wet weight)				
	Sr^{89}	Sr^{90}	Zr-Nb^{95}	Ru^{106}	Cs^{137}
Caribou					
Arctic herd					
10/2/62	<5	25	<10	<10	740
10/2/62	<5	74	<10	<10	<10
10/2/62	<5	79	<10	250	1,200
10/2/62	<5	73	<10	710	1,500
10/2/62	<5	85	<10	970	1,400
4/23/63	<5	15	<10	<10	4,400
4/23/63	<5	9	<10	<10	2,200
4/23/63	40	32	<10	<10	4,700
4/24/63	<5	12	<10	<10	6,200
4/24/63	<5	14	<10	<10	5,500
12/21/63			<10	<10	5,160
12/21/63	[a] <5	[a] 17	<10	<10	5,680
12/21/63			<10	80	3,750
4/27/64			<10	<10	21,000
5/3/64			<10	<10	16,000
5/19/64			<10	<10	9,900
5/19/64			<10	<10	17,000
5/19/64			<10	1,300	5,000
8/20/64			<10	<10	740
8/28/64			<10	<10	660
8/28/64			<10	<10	400
8/28/64			<10	<10	1,000
8/29/64			<10	<10	710
Nelchina herd					
11/24/63			<10	2,120	25,500
11/24/63			<10	870	16,900
11/25/63	[a] 5	[a] 33	<10	<10	18,200
11/25/63			<10	<10	22,100
11/25/63			<10	1,290	26,400
4/24/64			<10	13,000	3,500
4/24/64			<10	13,000	3,000
4/25/64			<10	12,000	2,600
4/25/64			<10	<10	10,000
4/26/64			<10	<10	8,700
Peninsula herd					
12/12/63			<10	<10	39,400
12/12/63			<10	240	41,500
12/13/63	[a] 10	[a] 84	200	190	33,600
12/19/63			<10	<10	57,700
12/19/63			<10	350	51,700
4/9/64			<10	<10	18,000
4/12/64			<10	<10	16,000
4/15/64			<10	<10	12,000
4/15/64			<10	<10	16,000
4/15/64			<10	<10	12,000
7/11/64			<10	<10	1,400
7/11/64			<10	<10	1,800
7/11/64			<10	<10	1,500
7/11/64		<10	<10	<10	2,000
9/26/64			<10	<10	1,200
9/26/64			<10	160	2,380
9/26/64			<10	200	2,090
10/1/64			<10	2,350	9,250
10/1/64			<10	1,190	8,010
Reindeer					
Area 1					
12/27/63			<10	<10	7,540
12/27/63			<10	<10	7,180
12/27/63	[a] <5	[a] 31	<10	<10	6,730
12/27/63			<10	<10	7,300
9/7/64			<10	<10	4,900
9/7/64			<10	<10	3,100
9/7/64			<10	920	3,000
9/7/64			<10	<10	3,400
9/7/64			<10	610	2,300
Area 3					
9/26/64			<10	4,540	25,800
9/26/64			<10	1,970	15,400
Area 4					
9/25/64			<10	4,020	770
9/25/64			<10	1,950	10,100
9/25/64			<10	950	7,670
Area 8					
9/18/64			<10	1,410	6,730
9/18/64			<10	<10	8,360
9/18/64			<10	<10	5,930
9/18/64			<10	<10	9,200
9/18/64			<10	<10	5,000
Area 9					
9/24/64			<10	450	5,900
9/24/64			<10	730	3,920
9/24/64			<10	1,200	7,530
9/24/64			<10	990	2,080

[a] Indicates composite of samples for the period analyzed.

At this stage, comparison of rumen content and muscle concentrations does not reveal any consistent relationship. The need for additional information, including more specific information concerning the dietary habits of caribou is required before meaningful comparisons can be made.

TABLE 2.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER RUMEN CONTENTS

Specimens & sampling dates	(pc/kg)				
	Sr^{89}	Sr^{90}	Zr-Nb^{95}	Ru^{106}	Cs^{137}
Caribou					
Arctic herd					
12/21/63			5,400	3,930	3,980
12/21/63	[a] 500	[a] 4,440	5,740	3,910	4,700
12/21/63			5,810	4,390	4,540
4/27/64			<10	13,000	4,100
5/3/64			<10	14,000	4,000
5/19/64			<10	14,000	4,100
5/19/64			<10	13,000	6,000
5/19/64			<10	15,000	4,000
8/20/64			<10	4,300	1,600
8/28/64			<10	5,800	970
8/28/64			<10	2,800	1,200
8/28/64			<10	4,400	2,200
8/29/64			<10	4,100	1,400
Nelchina herd					
11/24/63			12,590	10,370	5,680
11/24/63			9,350	6,460	7,430
11/25/63	[a] 550	[a] 5,700	1,910	1,590	1,100
11/25/63			7,970	6,540	4,480
11/25/63			9,410	7,010	5,710
4/24/64			<10	<10	7,500
4/24/64			<10	<10	10,000
4/25/64			<10	9,100	10,000
4/25/64			<10	12,000	2,500
4/26/64			<10	<10	12,000
Peninsula herd					
12/12/63			14,560	6,940	12,300
12/12/63			9,950	4,790	7,280
12/13/63			9,860	5,450	7,360
12/19/63			3,050	6,250	4,020
12/19/63			9,940	4,840	8,660
4/9/64			<10	4,600	2,600
4/12/64			<10	4,900	1,700
4/15/64			<10	3,300	1,600
4/15/64			<10	2,700	1,900
4/15/64			<10	3,200	1,400
7/11/64			<10	<10	620
7/11/64			<10	<10	740
7/11/64			<10	<10	680
7/11/64			<10	<10	670
7/11/64			<10	<10	720
9/26/64			<10	1,600	1,500
9/26/64			<10	4,350	2,790
9/26/64			<10	3,500	2,290
10/1/64			<10	13,100	9,550
10/1/64			<10	12,500	13,300
Reindeer					
Area 1					
12/27/63			4,870	2,930	5,150
12/27/63	[a] 5	[a] 5600	4,580	2,060	3,760
12/27/63			5,840	3,620	5,360
12/27/63			5,140	2,870	4,320
Area 4					
9/25/64			<10	<10	5,770
Area 8					
9/18/64			<10	<10	3,290
9/18/64			<10	<10	4,510
9/18/64			<10	<10	3,970
Area 9					
9/24/64			<10	<10	660
9/24/64			<10	<10	1,070
9/24/64			<10	<10	1,900

[a] Indicates composite of samples for the period analyzed.

TABLE 3.—RADIONUCLIDES IN ALASKAN CARIBOU AND REINDEER BONE

Specimens & sampling dates	Sr^{89} (pc/g ash)	Sr^{90} (pc/g ash)	$Zr\text{-}Nb^{95}$ (pc/kg) [a]	Ru^{106} (pc/kg) [a]	Cs^{137} (pc/kg) [a]
Caribou					
Arctic herd					
12/21/63	[b] 60	[b] 225	<10	450	190
12/21/63			<10	640	210
12/21/63			<10	910	120
4/27/64			[c] NA	NA	NA
5/3/64			NA	NA	NA
5/19/64	[b] <5	[b] 143	NA	NA	NA
5/19/64			NA	NA	NA
5/19/64			NA	NA	NA
Nelchina herd					
11/24/63			<10	4,550	520
11/24/63			<10	3,210	620
11/25/63	[b] <5	[b] 117	<10	1,910	620
11/25/63			<10	1,510	900
11/25/63			<10	3,860	1,940
4/24/64			NA	NA	NA
4/24/64			NA	NA	NA
4/25/64	[b] <5	[b] 143	NA	NA	NA
4/25/64			NA	NA	NA
4/26/64			NA	NA	NA
Peninsula herd					
12/12/63			460	350	3,240
12/12/63			<10	430	4,780
12/13/63	[b] <5	[b] 118	<10	490	3,740
12/19/63			<10	<10	3,660
12/19/63			<10	380	4,210
4/9/64			NA	NA	NA
4/12/64			NA	NA	NA
4/15/64	[b] <5	[b] 116	NA	NA	NA
4/15/64			NA	NA	NA
4/15/64			NA	NA	NA
9/26/64			<10	820	420
9/26/64			<10	<10	460
10/1/64			<10	400	1,000
10/1/64			<10	550	2,180
Reindeer					
Area 1					
12/27/63			<10	<10	750
12/27/63	[b] 25	[b] 64	<10	<10	850
12/27/63			<10	<10	800
12/27/63			<10	<10	920
9/7/64			<10	<10	2,700
9/7/64			<10	<10	1,300
9/7/64			<10	260	1,500
9/7/64			<10	710	3,400
9/7/64			<10	<10	2,300
Area 3					
9/26/64					1,890
9/26/64			<10	<10	5,460
Area 4					
9/25/64			<10	<10	1,080
9/25/64			<10	590	2,880
9/25/64			<10	840	2,180
Area 8					
9/18/63			<10	<10	1,520
9/18/64			<10	<10	1,380
9/18/64			<10	<10	1,060
9/18/64			<10	<10	1,790
9/18/64			<10	<10	1,340
Area 9					
9/24/64			<10	400	520
9/24/64			<10	390	350
9/24/64			<10	530	610
9/24/64			<10	<10	330

[a] Wet basis.
[b] Indicates composite of samples for the period analyzed.
[c] Indicates no analysis was done.

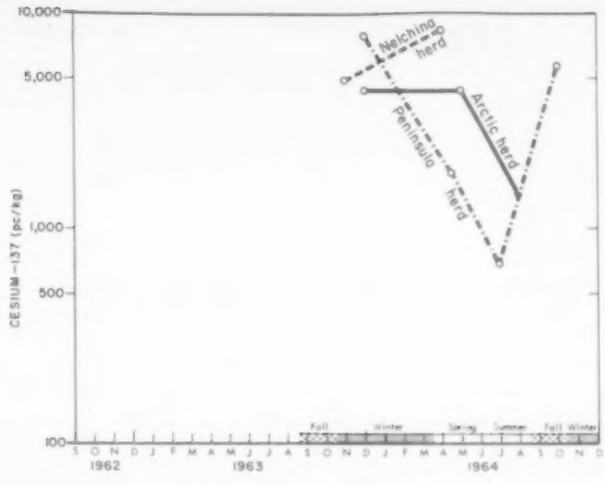

FIGURE 3.—CESIUM-137 IN CARIBOU RUMEN CONTENTS

Although the data are too limited to permit detailed analysis, some observations may be made from the cesium–137 in muscle data for the Arctic Herd. Although a general increasing trend is noted from 1962 through 1963, seasonal variations are difficult to ascertain. Of special interest is the apparent rapid decrease in flesh concentration during the summer of 1964. If the individual data for the Arctic Herd are plotted, they imply an effective half-life for cesium–137 in caribou flesh of approximately 25 days (assuming no intake of cesium–137 during the period). Whether this represents actual turnover in caribou or simply the absence of a close relationship between samples cannot be answered from these data.

STRONTIUM-90 IN HUMAN BONE, 1962-1963

George W. Gaffney, Robert M. Hallisey, Marshall S. Miller, and Abraham S. Goldin[1]

The need to establish Public Health Service programs to provide estimates of accumulations of selected radionuclides in people was emphasized in statements of objectives and feasibility studies initiated in 1961 and 1962 (*1-3*). These estimates would be based on direct measurements in human organs and tissues and would initially include measurement of strontium–90 in bone and iodine–131 in thyroids.

In late 1961 the Public Health Service's Division of Radiological Health, jointly with pathologists and medical examiners throughout the U.S., initiated collection of human bone specimens at autopsies or incidental to surgical procedures. The background of this program, review of previous work, description of analytical methods employed, and initial results from determinations made through October 1963 are given in a previous report (*4*). This report analyzes the results obtained in the program through June 1964, and also gives detailed data for determinations completed from November 1963 through June 1964.

Results

Each determination included in this report represents a separate individual. Table 1 incorporates, for deaths occurring in 1962 and 1963, all results of analyses performed in the Strontium–90 in Human Bone Program through June 1964. This analysis supplants that previously reported (*4*) and includes data for a total of 322 individuals who died in 1962 and 1963 at ages less than 25 years. The present analysis does not include data previously reported for 8 individuals who died in 1961. The program was not designed to include individuals 25 years or older. Analyses from older age groups support the expectation that relatively low strontium–90 to calcium ratios would be found in these cases.

Table 1 contains the highest, lowest, and mean strontium–90 observed in the Programs in bone specimens for each of 5 age ranges and 6 major geographic regions in the United States, as well as for the entire United States. For each category considered, the number of individuals from whom specimens were obtained and analyzed is also given. The 6 major geographic regions (figure 1) have been arbitrarily designated for use in the program (*4*).

Table 2 supplements detailed data which were previously reported (*4*). Details are given for each determination in the program from November 1963 through June 1964.

Figure 2 shows the frequency distribution for strontium–90 in the bone samples from 1962 and 1963 deaths. The distribution is skewed in all of the age ranges considered in this report and the distribution of strontium–90 was observed to be similarly skewed. The logarithmic probability plot presented in figure 3 clearly indicates that the distribution is log-normal, consistent with earlier observations by Kulp and Schulert on whole skeleton samples obtained in New York (*5*).

Figure 4 is a plot of mean strontium–90 versus age for each age range and also a plot of the standard errors of the mean for strontium–90 found for each age group. In view of figures 2 and 3 as noted above, means and standard errors of the mean are certainly not entirely

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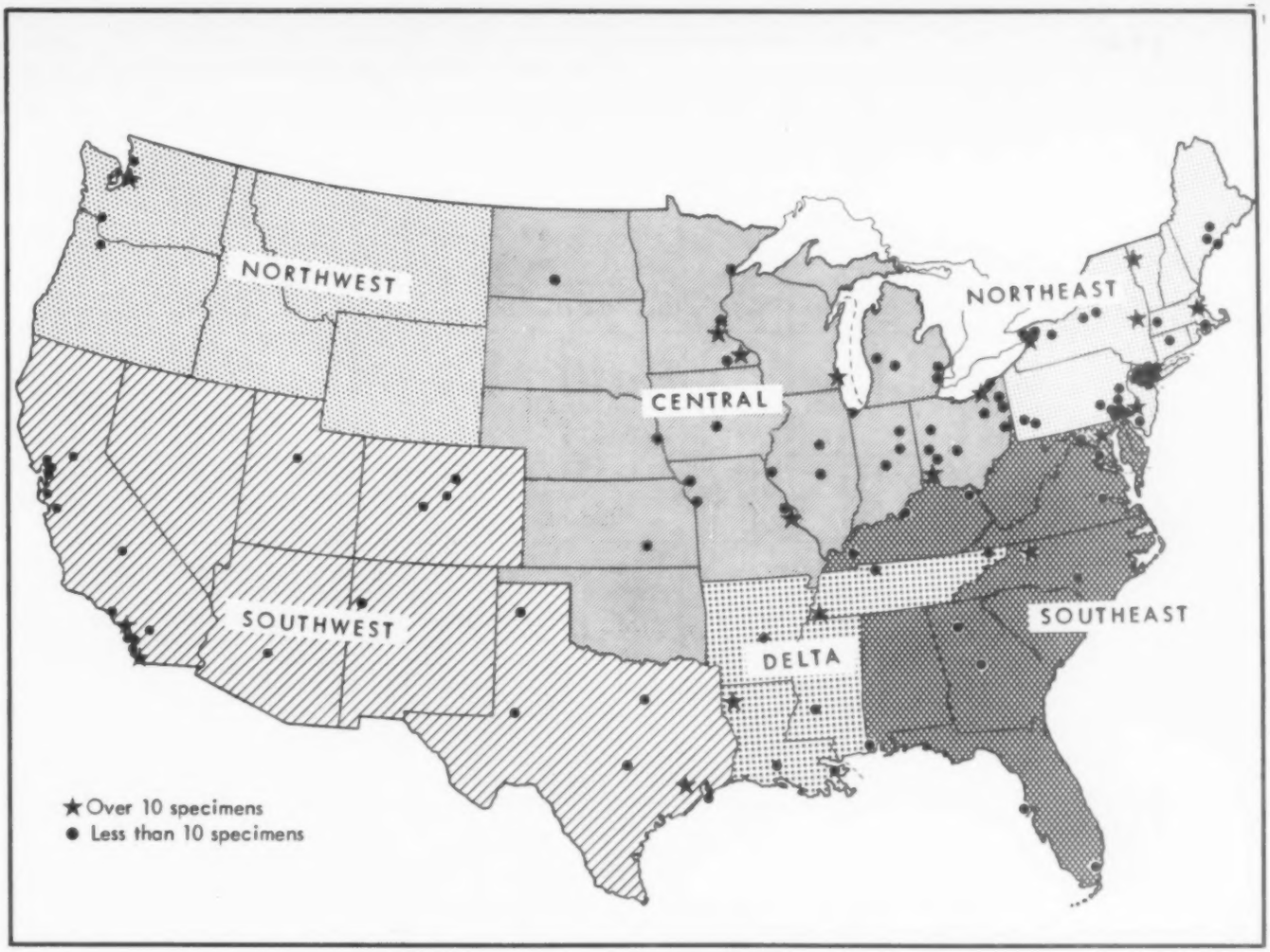

FIGURE 1.—REGIONS FOR PHS BONE SAMPLING PROGRAM AND LOCATION OF COLLECTION CENTERS

satisfactory statistics for these data, which clearly are not normally distributed. Nevertheless, means and standard errors of the mean are given in this report (table 1 and figure 4) because:

1) These have been frequently used by others in reports of strontium–90 in bone; they are in some cases the only basis for comparison with results of previous work by others;
2) Even for a skewed distribution, the mean value could be meaningful for epidemiologic dose and effect interrelationships;
3) The standard error of the mean
   (a) communicates some idea, in an abbreviated summary, of the uncertainty in the central value and,
   (b) combined with information on the number of individuals in the sample, gives some idea of the spread in the distribution of the individual values.

Figure 5 is a plot of median strontium–90 versus age for deaths occurring in 1962 and 1963. In each age group there appeared to be higher median values in samples from 1963 deaths as compared with those which occurred in 1962. Even though the median might be considered as a better estimate of central values, similar conclusions regarding the general rise in strontium levels in bone in 1963 over those found in the corresponding age groups in 1962 deaths might be drawn from the mean values given in figure 4. In both figures the most prominent changes are seen in the youngest age groups.

Inspection of table 2 and the corresponding table in a previous report (*4*) indicates that the median values for the 0–4 age group would be even higher if neonatal deaths (birth to one month) were excluded. There is good reason, in fact, to consider separately those cases in which death occurs in the first few months of

TABLE 1.—SUMMARY OF STRONTIUM-90 IN HUMAN BONE IN SELECTED DEATHS OCCURRING IN THE UNITED STATES IN 1962 AND 1963, BY YEAR OF DEATH, AGE AND GEOGRAPHIC ORIGIN. This table incorporates data for all individual cases from whom one or more bone specimens were analyzed in the Strontium-90 in Human Bone Program through June 1964. The "maximum" and "minimum" for each category are the highest and lowest values found in analysis of specimens from individual cases in the category. For comment regarding the average values, in view of the non-normal distribution in strontium units (Figures 1 and 2), see text.

[pc Sr^{90}/g calcium]

Region	1962 DEATHS																				Total No.
	0–4 yrs.				5–9 yrs.				10–14 yrs.				15–19 yrs.				20–24 yrs				
	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	
Northeast	4.8	1.6	9.7	9	5.1	2.4	9.4	7	2.8	1.8	4.7	7	2.7	1.1	4.6	8	2.1	1.3	4.9	12	43
Southeast	5.8	5.2	6.3	2	3.4	3.4	3.4	1	2.5	2.0	3.0	2	2.5	1.9	3.0	4	1.9	1.4	2.2	6	15
Central	2.6	0.8	7.2	34	2.1	1.3	2.7	22	2.1	0.8	3.5	13	2.0	1.2	3.4	12	1.8	0.9	2.8	8	89
Delta	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	1.8	1.8	1.8	1	1
Northwest	2.9	2.9	2.9	1	.....	.....	.....	.....	2.1	1.8	2.6	3	1.8	1.3	2.4	4	1.7	1.4	2.4	3	11
Southwest	4.9	3.0	6.8	2	1.7	1.7	1.7	1	2.0	2.0	2.0	1	2.0	1.0	3.0	2	0.9	0.9	0.9	1	7
All	3.2	0.8	9.7	48	2.8	1.3	9.4	31	2.3	0.8	4.7	26	2.2	1.0	4.6	30	1.9	0.9	4.9	31	166
	1963 DEATHS																				Total No.
	0–4 yrs.				5–9 yrs.				10–14 yrs.				15–19 yrs.				20–24 yrs.				
	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	Mean	Min	Max	No.	
Northeast	6.9	1.2	13.0	13	4.6	2.8	9.1	20	3.8	1.4	9.0	14	2.9	1.6	4.8	30	2.4	1.6	3.7	17	94
Southeast	1.9	1.9	1.9	1	.....	.....	.....	.....	2.0	2.0	2.0	1	3.6	3.3	3.9	2	1.9	1.5	2.4	4	8
Central	3.3	2.3	6.8	14	2.8	1.8	4.2	3	2.3	1.7	3.6	12	1.8	1.0	2.7	5	5.0	5.0	5.0	1	35
Delta	.....	.....	.....	.....	4.2	4.2	4.2	1	2.9	2.9	2.9	1	4.4	2.5	7.0	4	2.5	1.8	3.3	4	10
Northwest	4.1	3.5	4.7	2	2.4	2.2	2.6	2	3.8	1.8	5.9	2	.....	.....	.....	.....	.....	.....	.....	.....	6
Southwest	.....	.....	.....	.....	3.8	3.8	3.8	1	2.8	2.8	2.8	1	1.6	1.6	1.6	1	.....	.....	.....	.....	3
All	4.7	1.2	13.0	30	4.2	1.8	9.1	27	3.1	1.4	9.0	31	2.9	1.0	7.0	42	2.4	1.5	5.0	26	156

life because of the discrimination between strontium and calcium by the mother in absorption, excretion, and transplacental passage as well as for reason of diets frequently lower in strontium units during the first few months after birth.

These factors would be expected to manifest themselves by relatively lower strontium units in bone during the first few months of life and would subsequently be offset by accumulation of relatively higher radiostrontium levels from dietary sources in the absence of the maternal discrimination. That this effect is marked and prolonged during the first few months of life is consistent with observations given in table 3. Following the rise to relatively higher levels after the first months of life, there is a gradual decrease in strontium units in bone with increasing age. The observed regression on age holds true not only for combined results on specimens obtained throughout the nation, but generally for the six geographic regions, both in 1962 and 1963, except in those cases in which the number of specimens was too small to permit any inferences to be drawn.

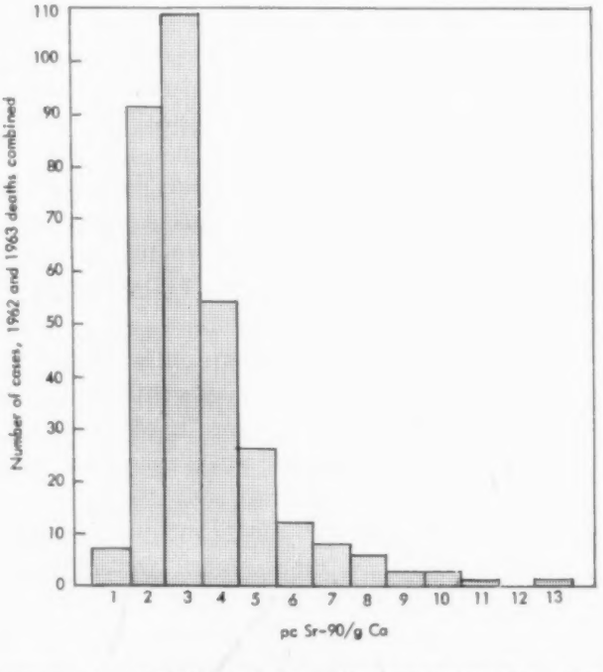

FIGURE 2.—FREQUENCY DISTRIBUTION FOR STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE FROM SELECTED U. S. DEATHS IN 1962 AND 1963. The distribution is skewed. The data include results for all individual cases for which specimens were analyzed in the strontium–90 in human bone program through June 1964.

TABLE 2.—DETAILED DATA FOR INDIVIDUAL CASES, BONE SPECIMENS AND STRONTIUM-90 ANALYTICAL RESULTS. The table includes data for all individual cases for which analyses of strontium-90 content in bone were performed in the Strontium-90 in Human Bone Program in the interval from November 1963 through June 1964.

Region, State, and sample	Age at death	Sex	Date of death	Bone *	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of—			2σ counting error (%)
							Ash	Ca	Bone	
Northeast										
Conn.										
I-16(0001)	5 y	M	Sep 63	V, R	89	11.3	1.1	2.8	0.13	9
I-16(0002)	20 y	M	Sep 63	V, I	97	13.5	1.2	3.2	0.16	20
I-16(0002)	2 y	M	Sep 63	V, I	97	13.5	1.4	3.7	0.19	17
I-16(0002)	2 y	M	Sep 63	V, I	97	13.5	1.5	4.2	0.22	17
I-16(0003)	9 y	M	Oct 63	V	128	10.2	1.5	4.1	0.12	13
I-16(0005)	7 y	M	Oct 63	V, I	278	22.9	1.6	4.3	0.13	6
I-16(0006)	24 y	F	Nov 63	V	88	13.6	1.2	3.2	0.19	11
I-16(0007)	6 y	M	Dec 63	V, R	106	10.8	1.6	4.4	0.16	11
Maine										
I-9(0002)	18 y	M	Aug 63	I	80	17.2	0.50	1.5	0.13	26
I-9(0002)	18 y	M	Aug 63	I	80	17.2	0.81	2.0	0.16	12
Mass.										
I-2(0007)	12 y	M	Jun 63	V	112	11.5	1.9	5.0	0.19	19
I-2(0010)	2 y	M	Jul 63	V	125	9.4	2.5	7.3	0.19	11
I-2(0011)	5 y	F	Jul 63	V	144	12.4	1.4	4.0	0.12	13
I-2(0013)	14 y	F	Jul 63	V	207	17.7	1.2	3.6	0.11	16
I-2(0016)	10 y	F	Jul 63	V	116	14.9	0.61	1.9	0.09	31
I-2(0016)	10 y	F	Jul 63	V	116	14.8	0.75	2.0	0.10	7
I-2(0018)	1 y	F	Jul 63	V	67	5.7	2.3	7.7	0.23	8
I-2(0019)	5 y	F	Jul 63	V	169	14.3	1.7	5.0	0.16	14
I-2(0019)	5 y	F	Jul 63	V	169	14.3	1.8	5.4	0.16	11
I-2(0022)	15 y	F	Aug 63	V	123	14.3	1.2	3.3	0.14	20
I-2(0025)	5 y	M	Aug 63	V	169	13.6	2.1	5.7	0.17	13
I-2(0026)	9 y	M	Aug 63	V	103	10.5	1.1	3.2	0.12	10
I-2(0028)	10 y	F	Sep 63	V, R	111	11.8	1.2	3.1	0.13	14
I-2(0035)	17 y	M	Sep 63	V	223	22.4	0.80	2.2	0.08	9
I-2(0035)	17 y	M	Sep 63	V	223	22.4	0.84	2.3	0.08	7
I-2(0036)	8 y	M	Sep 63	V	96	9.1	1.3	3.7	0.12	12
I-2(0037)	14 y	F	Oct 63	V	118	16.1	1.3	3.7	0.18	16
I-2(0039)	10 y	M	Oct 63	V	226	17.9	0.42	1.4	0.04	29
I-2(0040)	12 y	M	Oct 63	V	75	8.3	1.7	4.7	0.19	11
I-2(0041)	16 y	F	Oct 63	V	152	17.3	1.4	3.7	0.14	8
I-2(0041)	16 y	F	Oct 63	V	152	17.3	1.6	4.2	0.18	7
I-2(0041)	16 y	F	Oct 63	V	456	17.3	1.8	4.7	0.22	7
I-2(0042)	3 y	F	Oct 63	V	70	5.0	2.5	6.9	0.18	13
I-2(0043)	7 y	M	Oct 63	V	81	8.1	2.6	7.5	0.26	19
I-2(0043)	7 y	M	Oct 63	V	81	8.1	2.6	7.6	0.27	4
I-2(0044)	13 y	F	Oct 63	V	94	11.4	1.7	4.7	0.21	3
I-2(0045)	6 y	M	Oct 63	V	84	5.5	3.1	9.1	0.20	17
I-2(0046)	3 y	M	Oct 63	V	166	9.2	4.6	13.0	0.25	10
I-2(0048)	4 y	F	Nov 63	V	68	5.7	2.9	8.0	0.24	11
I-2(0049)	19 y	F	Nov 63	V	85	9.6	1.3	3.4	0.14	10
I-2(0050)	20 y	M	Nov 63	V	111	14.4	1.2	3.4	0.15	20
I-2(0050)	20 y	M	Nov 63	V	222	14.4	1.5	4.0	0.21	3
I-2(0051)	14 y	M	Nov 63	V	168	16.2	0.96	2.6	0.09	9
I-2(0052)	3 y	M	Nov 63	V	168	13.1	2.0	5.3	0.16	8
I-2(0052)	3 y	M	Nov 63	V	168	13.1	3.0	7.7	0.23	7
I-2(0053)	11 y	F	Nov 63	V	141	12.2	3.1	9.0	0.27	6
I-2(0055)	9 y	M	Dec 63	V	257	23.4	1.6	4.2	0.15	5
I-2(0056)	18 y	M	Dec 63	V	228	24.7	0.98	2.6	0.11	8
I-2(0057)	3 y	F	Dec 63	V	98	7.4	1.7	5.2	0.19	12
I-2(0057)	3 y	F	Dec 63	V	98	7.4	2.4	6.6	0.22	88
I-2(0058)	19 y	M	Dec 63	V	144	14.1	0.90	2.5	0.09	10
I-2(0060)	6 y	M	Dec 63	V	100	9.5	2.1	6.1	0.20	8
I-2(0061)	2 y	M	Dec 63	V	103	8.2	2.8	8.5	0.21	8
Pa.										
II-19(0017)	19 y	M	Dec 62	V	153	23.6	0.63	1.7	0.10	24
II-19(0020)	20 y	M	Feb 63	V	190	23.9	0.65	1.8	0.09	22
Vt.										
I-6(0021)	20 y	F	Jun 63	V	95	15.3	0.78	2.1	0.12	23
I-6(0021)	20 y	F	Jun 63	V	95	15.3	1.0	2.6	0.17	30
I-6(0023)	9 y	M	Jun 63	V	150	16.1	1.1	2.9	0.12	13
I-6(0027)	18 y	M	Aug 63	V	144	18.3	0.90	2.4	0.12	19
I-6(0027)	18 y	M	Aug 63	V	144	18.3	1.1	3.0	0.14	17
I-6(0029)	18 y	M	Sep 63	V	104	15.5	1.0	2.8	0.18	18
I-6(0029)	18 y	M	Sep 63	V	104	15.5	1.2	3.2	0.16	10
I-6(0032)	15 y	M	Dec 63	V	146	20.2	1.3	3.6	0.18	11
I-13(0001)	2 y	M	Jul 63	V	118	12.7	3.4	10.1	0.39	10
I-13(0001)	2 y	M	Jul 63	V	118	12.7	4.0	11.8	0.45	6
I-13(0002)	8 y	M	Aug 63	V	180	15.6	1.1	3.2	0.10	19
I-13(0003)	15 y	M	Sep 63	V	155	20.8	0.80	2.0	0.10	21
I-13(0003)	15 y	M	Sep 63	V	155	20.8	0.84	2.4	0.12	8
I-13(0004)	14 y	F	Nov 63	V	110	14.1	1.5	3.2	0.18	8
I-13(0004)	14 y	F	Nov 63	V	221	14.1	1.6	4.3	0.22	3
Southeast										
Fla.										
IV-4(0001)	16 y	M	Aug 63	V, R	177	18.6	1.2	3.3	0.13	8

TABLE 2.—Continued

Region, State, and sample	Age at death	Sex	Date of death	Bone *	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of—			2σ counting error (%)
							Ash	Ca	Bone	
Central										
Mich.										
V-13(0005)	15 y	M	Nov 62	V	111	17.1	0.73	1.9	0.11	11
V-13(0015)	15 y	M	Nov 62	V	111	17.2	0.87	2.3	0.13	32
Minn.										
VI-6(0003)	21 y	M	Nov 62	V, S	252	32.7	0.36	0.93	0.05	25
VI-6(0005)	16 y	M	Dec 62	V	112	15.3	0.56	1.5	0.08	14
VI-6(0005)	16 y	M	Dec 62	V	112	14.5	0.91	2.4	0.11	25
Mo.										
VI-2(0029)	16 y	M	Jan 63	R	36	14.2	0.57	1.5	0.27	28
VI-2(0029)	16 y	M	Jan 63	R	36	14.2	0.72	1.8	0.23	31
Ohio										
V-16(0001)	20 y	M	Nov 62	V	80	12.8	0.79	2.1	0.13	25
V-16(0001)	20 y	M	Nov 62	V	80	12.9	1.3	3.5	0.21	20
V-16(0006)	19 y	M	Apr 63	V	147	21.6	0.34	0.96	0.05	44
V-17(0002)	18 y	M	Dec 62	V	131	20.1	0.43	1.2	0.07	33
V-17(0002)	18 y	M	Dec 62	V	131	20.2	0.57	1.6	0.09	25
V-17(0006)	8 y	M	Apr 63	V	162	17.4	0.86	2.3	0.09	21
V-19(0016)	5 y	M	Jan 62	V	274	24.9	0.83	2.3	0.08	8
V-19(0017)	2 y	M	Jan 62	V	107	11.6	1.1	2.9	0.12	11
V-19(0019)	10 m, 17 d	M	Jan 62	V	212	21.6	0.70	1.9	0.07	10
V-19(0020)	8 y	M	Jan 62	V	182	14.3	0.47	1.3	0.04	17
V-19(0021)	11 y	F	Feb 62	V	258	23.4	0.29	0.78	0.03	17
V-19(0022)	1 y	M	Feb 62	V	272	26.4	0.65	1.8	0.06	6
V-19(0026)	2 d	F	Feb 62	V	125	12.5	0.33	0.90	0.03	21
V-19(0027)	8 y	M	Mar 62	V	314	19.3	0.46	1.4	0.03	15
V-19(0028)	12 y	M	Apr 62	V	414	19.4	0.81	2.2	0.07	11
V-19(0028)	12 y	M	Apr 62	V	207	19.4	0.81	2.4	0.08	10
V-19(0029)	2 y	M	Apr 62	V	140	9.5	0.79	2.3	0.05	16
V-19(0030)	6 m, 20 d	M	Apr 62	V	109	16.8	0.78	2.1	0.12	8
V-19(0031)	3 d	M	Apr 62	V	156	20.1	0.36	1.0	0.05	14
V-19(0031)	3 d	M	Apr 62	V	156	20.1	0.49	1.3	0.06	18
V-19(0032)	4 y	M	May 62	V	150	12.5	0.72	2.0	0.06	14
V-19(0033)	13 y	M	May 62	V	111	12.3	0.51	1.4	0.06	25
V-19(0037)	4 y	M	May 62	V	204	19.2	0.61	1.7	0.06	12
V-19(0038)	6 y	M	May 62	V	215	20.2	0.71	2.0	0.07	10
V-19(0040)	9 y	M	Jun 62	V	202	20.9	0.70	1.9	0.07	10
V-19(0041)	9 y	F	Jun 62	V	154	15.8	0.50	1.4	0.05	14
V-19(0042)	4 y	F	Jun 62	V	137	10.3	0.66	1.9	0.05	17
V-19(0043)	4 y	M	Jun 62	V	230	22.1	0.67	1.8	0.06	10
V-19(0045)	13 y	F	Jul 62	V	243	15.5	0.47	1.3	0.03	15
V-19(0045)	13 y	F	Jul 62	V	243	15.5	0.70	1.9	0.04	13
V-19(0046)	8 m	F	Jun 62	V	116	18.9	0.98	2.5	0.16	9
V-19(0047)	1 m, 29 d	M	Jul 62	V	96	12.2	0.63	1.7	0.08	14
V-19(0048)	11 m, 6 d	M	Jun 62	V	184	22.4	0.29	0.79	0.04	17
V-19(0049)	5 y	M	Jul 62	V	176	9.4	0.88	2.6	0.05	15
V-19(0050)	6 y	M	Aug 62	V	257	19.2	0.91	2.6	0.07	9
V-19(0051)	2 y	F	Jul 62	V	125	13.2	1.0	2.7	0.11	11
V-19(0052)	1 y, 6 m	M	Sep 62	V	170	19.3	1.3	3.7	0.15	8
V-19(0053)	4 y	M	Sep 62	V	234	24.3	1.1	3.1	0.12	8
V-19(0054)	3 y	M	Sep 62	V	132	9.6	1.1	3.1	0.08	12
V-19(0055)	9 y	M	Jul 62	V	188	18.4	0.54	1.5	0.05	28
V-19(0055)	9 y	M	Jul 62	V	188	18.5	0.88	2.5	0.09	10
V-19(0056)	7 m, 4 d	M	Sep 62	V	106	16.4	2.8	7.2	0.42	6
V-19(0058)	7 y	F	Oct 62	V	219	21.9	0.90	2.4	0.09	3
V-19(0059)	5 y	M	62	V	175	16.6	0.63	1.7	0.06	13
V-19(0059)	5 y	M	62	V	175	16.6	0.87	2.4	0.08	12
V-19(0060)	3 y	F	Sep 62	V	146	18.2	1.2	3.2	0.15	8
V-19(0061)	Stillborn	F	Aug 62	V	107	14.4	0.70	1.9	0.09	13
V-19(0062)	2 y	F	Sep 62	V	121	13.0	0.88	2.4	0.09	14
V-19(0064)	4 y	F	Nov 62	V	148	10.9	0.76	2.1	0.06	14
V-19(0065)	10 y	M	Oct 62	V	198	19.9	0.88	1.5	0.05	4
V-19(0065)	10 y	M	Oct 62	V	198	19.9	0.72	2.0	0.07	11
V-19(0066)	15 y	M	Oct 62	V	170	18.6	0.61	1.6	0.06	10
V-19(0066)	15 y	M	Oct 62	V	170	18.6	0.65	1.8	0.07	12
V-19(0066)	15 y	M	Oct 62	V	679	18.6	0.69	1.9	0.08	10
V-19(0067)	3 y	F	Nov 62	V	200	18.6	0.70	1.9	0.06	11
V-19(0068)	11 y	F	Oct 62	V	134	14.5	0.52	1.4	0.05	13
V-19(0068)	11 y	F	Oct 62	V	134	14.5	0.62	1.7	0.07	14
V-19(0069)	1 y, 7 m	M	Oct 62	V	129	14.8	0.98	2.7	0.11	10
V-19(0070)	5 y	M	Nov 62	V	183	14.8	0.93	2.6	0.08	6
V-19(0071)	2 y	F	Nov 62	V	103	9.3	1.92	5.2	0.17	10
V-19(0072)	13 y	F	Oct	V	148	17.4	0.65	1.7	0.08	12
V-19(0072)	13 y	F	Oct 62	V	148	17.4	0.65	1.8	0.08	12
V-19(0073)	1 y, 9 m	F	Nov 62	V	218	11.4	0.74	2.2	0.04	15
V-19(0074)	9 y	F	Oct 62	V	166	18.1	0.73	2.0	0.08	11
V-19(0074)	9 y	F	Oct 62	V	166	18.1	0.54	1.4	0.06	13
V-19(0075)	10 m, 11 d	M	Oct 62	V	103	10.5	1.7	4.5	0.17	10

TABLE 2.—Continued

Region, State, and sample	Age at death	Sex	Date of death	Bone *	Original wt (g)	Ash wt (g)	pc Sr^{90}/g of—			2σ counting error (%)
							Ash	Ca	Bone	
Central—Continued										
Ohio										
V-19(0076)	12 y	M	Aug 62	V	194	21.3	0.40	1.1	0.04	12
V-19(0076)	12 y	M	Aug 62	V	194	21.3	0.33	0.90	0.04	12
V-19(0079)	3 m, 13 d	M	Jan 63	V	100	8.4	1.2	3.4	0.10	14
V-19(0080)	5 y	M	Dec 62	V	164	16.3	0.82	2.2	0.08	11
V-19(0081)	9 y	F	Dec 62	V	226	20.9	0.86	2.3	0.08	9
V-19(0082)	9 y	M	Jan 63	V	248	18.5	0.64	1.8	0.05	12
V-19(0083)	3 y	F	Dec 62	V	110	8.8	1.2	3.3	0.09	13
V-19(0084)	11 y	M	Jan 63	V	177	12.8	0.64	1.8	0.07	16
V-19(0087)	6 y	F	Dec 62	V	187	20.9	0.85	2.3	0.09	11
V-19(0088)	1 y, 11 m	F	Dec 62	V	111	9.5	0.78	2.1	0.07	15
V-19(0090)	Stillborn	M	Dec 62	V	123	14.3	1.2	3.1	0.13	10
V-19(0091)	2 y	M	Dec 62	V	155	13.7	0.88	2.4	0.08	11
V-19(0092)	1 y, 2 m	F	Jan 63	V	107	12.2	0.93	2.5	0.11	13
V-19(0093)	4 y	M	Jan 63	V	117	10.3	1.4	3.9	0.12	14
V-19(0094)	5 m, 8 d	M	Dec 62	V	103	12.5	1.1	3.0	0.14	11
V-19(0095)	Stillborn	M	Jan 63	V	102	12.7	0.49	1.3	0.06	18
V-19(0096)	4 y	M	Jan 63	V	131	12.2	0.83	2.3	0.08	12
V-19(0098)	7 y	M	Nov 62	V	211	20.3	0.60	1.6	0.06	12
V-19(0099)	14 y	M	Feb 63	V	158	17.9	0.84	2.2	0.09	11
Wisc.										
V-3(0011)	10 y	F	Jan 63	V	214	22.4	0.76	2.0	0.08	17
V-3(0030)	4 y	M	Apr 63	V	56	4.7	1.8	6.8	0.19	14
V-3(0031)	4 y	M	Apr 63	V	144	13.5	1.2	3.3	0.11	19
Delta										
La.										
VII-8(0001)	25 y	M	May 63	V, R	158	24.3	0.81	2.1	0.12	10
VII-8(0008)	7 y	F	Aug 63	V, R	143	15.6	1.6	4.2	0.17	8
VII-8(0009)	15 y	M	Aug 63	V	98	16.7	1.8	4.7	0.30	8
VII-8(0011)	22 y	F	Sep 63	V	142	16.4	0.98	2.6	0.11	9
VII-8(0012)	20 y	F	Sep 63	V	162	22.0	1.2	3.3	0.17	7
VII-8(0016)	15 y	F	Nov 63	V	212	27.1	2.5	7.0	0.32	5
VII-8(0017)	22 y	M	Nov 63	V	139	20.6	0.89	2.3	0.13	10
VII-8(0017)	22 y	M	Nov 63	V	139	20.6	0.99	2.5	0.15	9
Miss.										
IV-8(0001)	13 y	M	Oct 63	V, R	152	25.9	1.2	2.9	0.20	8
Tenn.										
IV-9(0001)	20 y	F	May 63	V	89	15.5	0.72	1.8	0.12	12
IV-9(0002)	25 y	M	May 63	V	105	15.9	0.66	1.8	0.10	12
IV-9(0002)	25 y	M	May 63	V	105	15.9	0.81	2.1	0.12	12
IV-9(0006)	17 y	M	Aug 63	V	130	21.3	0.99	2.5	0.16	8
IV-9(0007)	18 y	F	Aug 63	V	141	22.0	1.3	3.4	0.20	7
Southwest										
Calif.										
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.35	0.87	0.05	37
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.39	1.1	0.05	36
IX-9(0008)	15 y	F	Nov 62	V	136	18.8	0.41	1.1	0.06	39
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	0.46	1.2	0.06	30
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	0.59	1.6	0.08	12
IX-9(0009)	13 y	F	Oct 62	V	133	19.7	1.2	3.1	0.20	14
Texas										
VII-1(0007)	11 y	M	Mar 63	V	227	25.5	1.1	2.8	0.12	8
VII-11(0001)	15 y	F	Surg 63	F	126	28.9	0.63	1.6	0.13	10
VII-11(0003)	5 y	M	Sept 63	V, R, I	115	12.3	1.3	3.8	0.25	8

* V, vertebra; R, rib; I, ilium; S, sternum; F, femur.

TABLE 3.—MEAN STRONTIUM UNITS IN HUMAN BONE IN SELECTED UNITED STATES DEATHS AT AGES UNDER ONE YEAR AND AT 1–4 YEARS, AND FOR BOTH GROUPS COMBINED. The data include all 1962 and 1963 deaths in the designated age groups for which bone specimens were analyzed in the Strontium-90 in Human Bone Program through June 1964.

Year in which death occurred	Mean strontium units in age group		
	0–12 months	1–4 years	0–4 years
1962	2.5	3.5	3.2
1963	2.2	5.0	4.7

TABLE 4.—STRONTIUM-90 SKELETAL CONCENTRATIONS CORRESPONDING TO FEDERAL RADIATION COUNCIL RANGES (4).

[pc Sr^{90}/g calcium]

FRC Range	Population "average"	Individuals
I	0–5	0–15
II	5–50	15–150
III	50–500	150–1500

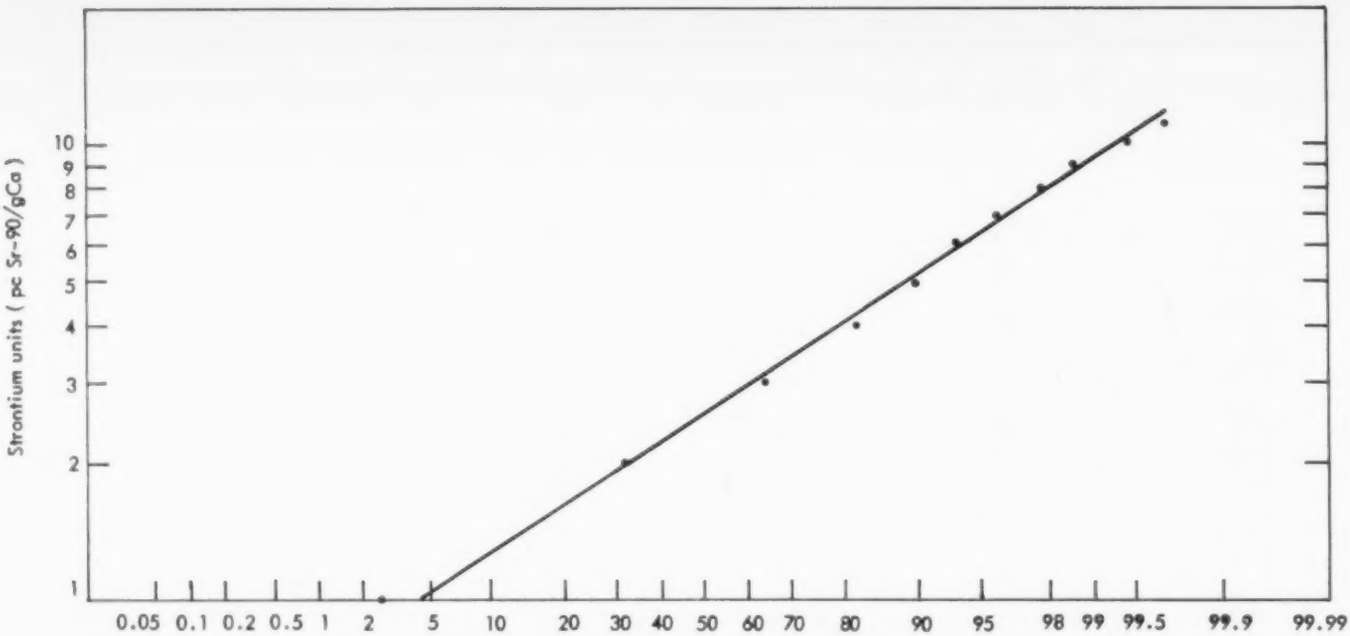

FIGURE 3.—PROBABILITY LOGARITHMIC PLOT OF STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE FROM SELECTED U.S. DEATHS IN 1962 AND 1963. The distribution is log-normal. The data include cumulative results for all individual cases for which specimens were analyzed in the strontium–90 in human bone program through June 1964.

While the results might, at first glance, appear to suggest that relatively higher strontium–90 bone levels have occurred in the Northeast than in other geographic areas, existing information does not permit adequate comparison of data from different geographic areas. For example, comparison of age-paired cases from the Northeast and the Central regions, which might be suggested by the relatively large numbers of specimens from these areas, is not feasible mainly for the reason that dates of death are not comparable.

Discussion

To investigate possible public health significance of data in this report it is of interest to compare these with strontium–90 skeletal concentrations which have been considered (*4*) to correspond to the three "ranges of transient rates of daily intake" cited by the Federal Radiation Council (*6*). The strontium–90 skeletal concentrations and the FRC intake "ranges" which have been related are listed for convenience in table 4. From bone data included in table 3 for two age groups, there is some suggestion that the skeletal concentration of strontium–90 considered to correspond to the upper limit of FRC Range I for the "population average" (table 4) was reached in 1963 for the 1–4 year age group (average value of 5 S.U.). The upper limit of the skeletal concentration related to FRC Range I for individuals was approached in one 1963 case; the value was 13 S.U. (table 1). However, it must be remembered that these data can only be absolutely related to the respective individual cases and not necessarily to a suitable sample of the exposed population.

Summary

Since late in 1961 the Public Health Service has conducted a program to provide estimates of strontium–90 levels in man. The authors analyzed data obtained through June 1964 in the Strontium–90 in Human Bone Program, and reported new analytical results, obtained from November 1963 through June 1964, for strontium–90 analyses of tissue from selected autopsies performed throughout the United States during 1962 and 1963. These were from cases less than 25 years old at death.

The distribution for strontium units (pc Sr^{90}/g Ca) in bone was log normal. Concentrations of strontium–90 in bone decreased with increasing age except during the first few months after birth. The latter observation is consistent with the well-known maternal discrimination against strontium in favor of calcium. This is believed to be principally responsible for the relatively low concentrations of strontium–90 in bone observed during the first few months after birth.

In the 1963 data, levels of strontium–90 in bone were higher than in individuals of similar ages who died in 1962. The observed average concentrations in 1963 in the 1–4 year age group correspond approximately to the upper limit of Range I of the guidance of the Federal Radiation Council (*6*). This guidance is used to provide some perspective of the strontium–90 burden even though the current FRC guidance does not indicate when protective action should be taken against fallout from nuclear weapons tests.

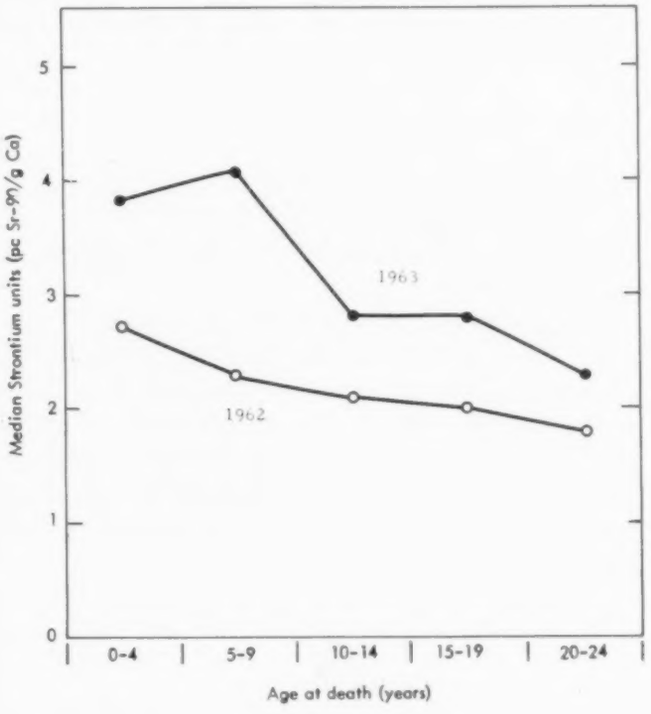

FIGURE 4.—MEAN STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE PLOTTED AGAINST AGE AT DEATH IN SELECTED U. S. DEATHS IN 1962 AND 1963. The data include all individual cases for which specimens were analyzed in the strontium–90 in human bone program through June 1964.

Vertical lines above and below the mean values represent one standard error of the mean in each direction. For comment regarding the average values and their standard errors, in view of non-normal distribution (figures 1 and 2), see text.

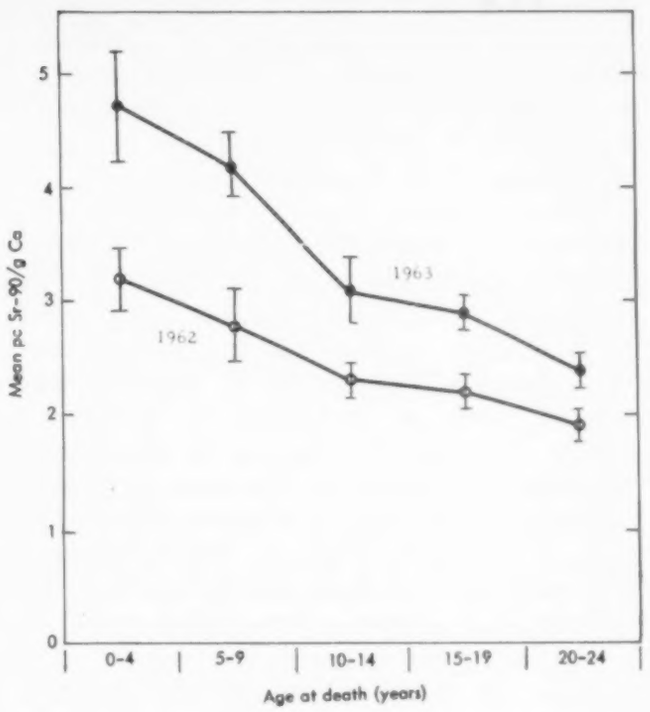

FIGURE 5.—MEDIAN STRONTIUM UNITS (pc Sr^{90}/g Ca) IN HUMAN BONE PLOTTED AGAINST AGE AT DEATH IN SELECTED U.S. DEATHS IN 1962 AND 1963. The data are based on the same analytical results as in figure 3.

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(*6*) Federal Radiation Council: *Background Material for the Development of Radiation Protection Standards, Report No. 2.* Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 20402 (September 1961), price 20 cents.

REPORTED NUCLEAR DETONATIONS, NOVEMBER 1964

During November 1964 one nuclear test was announced by the Atomic Energy Commission. This was an underground nuclear experiment conducted on November 5, at the Nevada Test Site as part of the Plowshare Program for peaceful uses of nuclear explosives.

The yield of this test was about 10 kilotons. It has been assigned the arbitrary *RHD* reference number 172.

Correction for Reported Nuclear Detonations, October 1964

In last month's summary of Reported Nuclear Detonations, *RHD* omitted a test conducted October 9 at the Nevada Test Site. This underground experiment, with a yield of about 30 kilotons, was part of the Plowshare Program.

The corrected chronological *RHD* reference numbers listed for October are, therefore, 167 through 171.

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December 1964

UNITS AND EQUIVALENTS

Symbol	Unit	Equivalent
Bev	billion electron volt	
cpm	count per minute	
dpm	disintegration per minute	
g	gram	
kg	kilogram	1 kg = 1000 gm = 2.2 pounds
km^2	square kilometer	
kvp	kilovolt peak	
m^3	cubic meter	1 m^3 = 1000 liters
ma	milliampere	
mas	milliampere-second	
Mev	million electron volts	
mi^2	square mile	
ml	milliliter	
mm	millimeter	
mrad	millirad	
mrem	millirem	
mr/hr	milliroentgen per hour	
mμc	millimicrocurie	1 mμc = 1 nc
nc	nanocurie	1 nc = 1000 pc = 1 mμc $=10^{-9}$ curies
nc/m^2	nanocurie per square meter	1 nc/m^2 = 1 $mμc/m^3$ = 1,000 $μμc/m^2$ = 1 mc/km^2 = 2.59 mc/mi^2
pc	picocurie	1 pc = 1 μμc = 10^{-12} curies
r	roentgen	
μμc	micromicrocurie	1 μμc = 2.22 dpm

INTERNATIONAL NUMERICAL MULTIPLE AND SUBMULTIPLE PREFIXES

Multiples and submultiples	Prefixes	Symbols	Pronunciations
10^{12}	tera	T	tĕr' a
10^{9}	giga	G	jĭ' ga
10^{6}	mega	M	mĕg' a
10^{3}	kilo	k	kĭl' o
10^{2}	hecto	h	hĕk' to
10	deka	da	dĕk' a
10^{-1}	deci	d	dĕs' i
10^{-2}	centi	c	sĕn' ti
10^{-3}	milli	m	mĭl' i
10^{-6}	micro	μ	mi' kro
10^{-9}	nano	n	năn' o
10^{-12}	pico	p	pē' co
10^{-15}	femto	f	fĕm' to

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